NASA TECHNICAL TRANSLATION NASA TT F-14,114

SPACE DEVELOPMENT IN EUROPE AND THE UNITED STATES OF AMERICA WITH EMPHASIS ON THE POST-APOLLO PROGRAM

Tetsuya Chiga

Translation of: Report No. 110 of Long-Range Space Program Study Team, Federation of Economic Organizations, Tokyo, Nov. 1971, 114 pages

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASINGTON, D. C. 20546 MARCH 1972

FOREWORD

Space development is one of the major sciences of the 70's together with ocean development and the peaceful uses of atomic energy. Our nation should also emphasize space development. There is no need to point out that space development is at the fore in technology and thus it has leadership and great influence in the advancement of science and technology.

Nevertheless, the space program in our country is still in its beginning stages. At present, a study is being carried out by the Committee for Space Development (the Chairman is Shiro Kiuchi, Minister of Science and Technology) and others which will prepare for the setting up and effective operation of a regular program in the future.

There is also a growing tendency nowadays to pursue the space development program within the scope of international cooperation as a common task for mankind rather than carrying it out separately in each nation. As a consequence, the United States of America invited both this country and the nations of Europe to join forces in carrying out the so-called "post-Apollo program" last year. International cooperation is also one of the basic aspects of space development in this country and is therefore being studied by the Committee.

With the above situations as a background, and in accordance with a request from the Committee for Space Development, the National Council for Space Development of this Federation (the Chairman is Hiroji (or Hiroharu) Kobayashi, the President of the Nippon Electric Co., Ltd.) formed a Long-Range Space Program Study Team and sent it to visit the United Kingdom, Germany, France and the United States of America during the period from the end of last June to the end of July in order to collect data and information as well as to find out the current situation in Europe and in the USA with regard to space development programs, especially the post-Apollo program. This book contains its report.

Science and technology advances so rapidly these days that yesterday's dreams have become today's realities. Our nation has considerable gaps in its technology as compared to the USA and the European countries. Unless our nation tries to develop an autonomous technology and makes remarkable efforts to remove those gaps in technology, this country will not only lag behind in this respect, but even the foundations of the national economy and social development may themselves be greatly affected in the future.

This book is published as a reference with the hope of deepening the understanding of everyone concerned with space development, which is to be a major branch of science from the 70's through the coming 21st century.

Teizo Horikoshi
Vice Chairman and Secretary General
Federation of Economic Organizations, Inc.

PREFACE

We, the members of the Long-Range Space Program Study Team, visited the United Kingdom, Germany, France and the United States of America, over a period extending from the end of June to the end of July of this year. The purpose was to collect data and information which would be used in the establishment of a long-range plan for a space program in our country as well as to investigate the current status of the space programs in Europe and the USA. In particular, it was our goal to look into the post-Apollo program with regard to its overall view, progress and prospects as well as problems which might arise in the course of international cooperation to carry out the program, since our country has also been invited to participate in the program.

The team visited the government agencies of the United Kingdom, Germany, France and the USA, the research organizations, centers and the headquarters of ESC (European Space Conference), ESRO (European Space Research Organization), ELDO (European Launcher Development Organization), and NASA (National Aeronautics and Space Administration) as well as the related private industries in those countries. Although the study was centered on the space shuttle, the space station and the space tug which were to be the agenda of the discussions at the round-table conference on the post-Apollo program set up by the Committee for Space Development, our investigation extended as much as possible to other subjects related to future problems in space development in our country.

When the team returned to Japan, it immediately began working on the full reports. It prepared at once a document called "Observations and Suggestions" and submitted it on the 24th of last August to the Committee for Space Development of the government, the Science and Technology Agency and other related departments to attract the attention of the responsible individuals. Later, it also reported at the Post-Apollo round-table conference of the Committee for Space Development on September 13th and at the National Council for Space Development of the Federation of Economic Organizations on the 22nd of the same month.

Space development, with the post-Apollo program at its center, has advanced much more than we thought in the USA and the European countries. We were very worried that our country might be left behind in world space development in the future unless our country took immediate steps. It is highly encouraging that the government acted so rapidly to conduct serious studies and to work in the near future on problems such as sending a liaison staff to NASA and reshuffling the internal organizations with an eye toward international cooperation, as pointed out by the team in its "Observations and Suggestions". It is hoped that the studies will be implemented step by step as soon as possible.

The activities of the study team were fairly tight ones timewise. However, we achieved the objectives more than adequately without too much trouble. This was only due to the cooperation of the members and I am very grateful to them. I would also like to express my sincere gratitude to the members of the government agencies and related industries in the USA and the European countries who offered considerable help in the study as well as to the staff members of the Japanese diplomatic and consular offices in those countries.

It will be fortunate if this report contributes to the establishment of a long-range space program in this country and to the progress of the space program in the future.

January 11, 1971

Tetsuya Chiga
Head
Long-Range Space Program Study Team

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SPACE DEVELOPMENT IN EUROPE AND THE UNITED STATES OF AMERICA WITH EMPHASIS ON THE POST-APOLLO PROGRAM

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ABSTRACT: The Long-Range Space Programs Study Team visited various NASA facilities and centers to discuss the post--Apollo program (space shuttle, space tug, Skylab, Viking). They also surveyed the European space scene. It was concluded that there is still an opportunity for Japan to cooperate in the space program; and that it is vital for her to do so if she is not to be left behind in the technological race.

OBSERVATIONS AND SUGGESTIONS /1*

I. Observations

The Post-Apollo program is a general name given to the space development programs succeeding the Apollo program of the United States of America. This program includes both manned and unmanned projects ranging widely from scientific research such as the space shuttle, space station, space tug, Viking and Grand Tour to planet exploration and the effective use of space.

1. Idea of the Post-Apollo Program

The idea of the Post-Apollo program is based on advancements in developing and applying this new area of space in order to improve the welfare and culture of mankind by utilizing the knowledge and technology obtained so far through space programs as well as by gathering the brains of the world to work together. This program was initiated in the United States of America, which achieved

* Numbers in the margin indicate pagination in the foreign text.

remarkable success in the area of space activities such as the Apollo program, on the assumption that the Apollo program was not the terminal point of space development but rather a beginning of space exploration and utilization by human beings. A characteristic feature of this program is the invitation to European nations and our country to participate in pursuing the program through international cooperation.

Recent space developments in the world are shifting the emphasis from pursuing national prestige and political goals to the realization of cultural improvement and promotion of the human welfare through international cooperation in scientific research and applications.

2. Movement Toward International Participation

It is possible for the USA to carry out the post-Apollo program without international participation. However, America hopes strongly for international participation in order to achieve much more in the program by drawing upon the extensive knowledge of all mankind.

The points emphasized by NASA in international participation are that the door is open to any suggestions and that the participation should be acted upon by each country with the individual responsibility of its own government. /2

In regard to this matter, the European countries rated its significance highly and were negotiating with the United States of America through ESC (European Space Conference). Although they had not officially announced their participation yet, they were preparing for participation and it was thought that they would participate eventually in the future despite some problems such as conditions and so on.

After witnessing the serious moves of the European countries and the USA in the post-Apollo program, we received a strong impression that there would be no doubt that our country would be left behind in the fields of research, development and utilization of space in the future unless our nation evaluated the significance and the future of the program correctly and took appropriate measures quickly.

3. Forecast of Program Achievement

It was considered that the Post-Apollo program would be successful although there might be some modifications (more or less) in the original plan in the content of the projects, frequencies and schedules due to economic and other reasons.

These reasons are: first, the major projects of the post-Apollo program have passed the paper-planning stage, elaborate research, experiments and development and are in the concrete stage; second, it was felt that the USA wanted to follow the idea of "space development by mankind" rather than "space development by the USA" and had a strong desire to secure its leadership; third, the aerospace industries in the USA have had to reduce their manpower by 40 to 70% and it was judged that the program was necessary for social and economic needs such as existence of the industries as well as for national needs for maintenance and improvement of the technology obtained through the Apollo program and so on.

4. Opportunity to Correct the Differences in Technology Levels

One of the reasons that the European countries indicated their willingness to participate in the post-Apollo program was considered to be the dissolution of the technological gaps between the USA and these countries. If we consider that a large gap exists in the technology of space development between our nation and Europe at the present time and that Europe has abundant manpower devoted to space science and research, it should be stated that our nation has an urgent task, to take concrete measures to fill the gap in this field. /3

5. Strengthening Links With Europe

Since there were many aspects of thinking and practice in Europe in regard to the space development program which could be good references, it was strongly felt that our nation should have a closer relationship, communicating and exchanging information with European countries as well as ESRO and ELDO.

6. Importance of Mission Study

Both Europe and the USA have expended a fair amount of money and human effort to perform a mission study prior to each of the projects, i.e., the so-called investigation of the fundamental stages, consisting of Phase A (the conceptual stage) and Phase B (the planning stage). This fact should be kept in mind in the establishment of the space development program in our country.

7. Importance of Technology

If we look at the attitudes of Europe and the USA toward the post-Apollo program, they have not been tied too much to current economic and social benefits, but rather have attached importance to cultural and academic values in order to pursue this technology.

8. Position in the World System

It was felt that our nation should consider worldwide trends in the study of the long-range view or the future plan for space development and should look ten years, twenty years or even thirty years into the future. Also, it was felt necessary to evaluate the role and position of our nation in this world system.

9. Possibility of Our Nation's Participation /4

1. When our nation considers participation in the post-Apollo program it is necessary to study the overall program rather than limiting ourselves to the space shuttle, space station and space tug.

2. Since the space station and space tug are in their conceptual stages, it is certainly possible to participate.

3. Although considerable progress has been made in Phase B of the study of the space shuttle, the possibility still exists to participate if our nation acts promptly.

4. Since various possibilities exist in the fields and forms of participation and cooperation, more studies should be made in the future for a concrete resolution. However, some examples may be given, as follows.

a. Research, experiments and observations using the space station and RAM (Research and Applications Module).

b. Development of the space station, RAM and tug.

c. Development of the research and observation apparatus and other equipment which will be aboard the space station, etc.

d. Development of various forms of theoretical research, basic research, computation and research and experimental techniques.

e. Cooperation in fields where mutual contributions can be made with the USA in regard to scientific satellites.

f. Offering ground facilities and supporting the operations.

5. In any case, the basic idea in international cooperation is "mutual contribution". Therefore, we realize that proposals which contain special features to be selected as international projects as well as suitable technology corresponding to the partners would be recognized in order to participate.

10. Lack of Information

If we could summarize the impressions obtained from the study in one word, the post-Apollo program has progressed beyond what we initially expected and we painfully realized that our nation had a tremendous information gap regarding this program, compared to the European countries who sent their full-time staffs to the United States of America. /5

II. Suggestions

From the above considerations, we suggest that our nation take the following measures:

1. In order to close the information gap, send liaison staff to NASA and other industries in the USA and establish a communication system with Europe, especially with ESC (ELDO, ESRO).

2. Internally, summarize the problems arising in international participation and cooperation and to transmit accurately the necessary information

and data to the government, academic world and industry and to set up an organization which will evaluate and adjust the suggestions made by those related fields.

3. For participation to the post-Apollo program, carry out thorough investigations and research regarding the significance of participation, its scope and our nation's ability by mobilizing brainpower in the related fields.

4. Establish a long-range space program for our nation after sufficient evaluation and investigation of the post-Apollo program and its achievements.

5. Take necessary measures for our nation's related industry to participate in an international consortium as related to the post-Apollo program.

6. Place more effort on educating and enlightening the people on the significance and international scope of the space program in order to obtain the understanding and support of the people.

7. Strive to secure sufficient funds for the above measures and to consider some type of arrangements between governments.

PART 1. OUTLINE OF POST-APOLLO PROGRAMS

1. NASA Projects

A schedule of the post-Apollo programs and NASA projects is summarized in Table 1.

2. Space Shuttle

(1). Outline

The space shuttle is being developed as a system which will transport /6
personnel, spacecraft, artificial satellites and other materials needed in the space activities, economically between the ground and comparatively lower orbits around the Earth.

The essence of this program is a piggyback concept, i.e., to load a rather small orbiter on the back of a booster which is shaped like an airplane. The booster and orbiter have two crew members each and can be launched vertically. The booster is separated from the orbiter approximately 200 seconds after the launch, approximately 250,000 feet (76 km) above the ground, and returns to the ground by horizontally landing like an airplane on a runway at the launch site. The orbiter will continue to climb after the separation and enter orbit around the Earth where it will finish its designated mission before returning to the Earth by the same horizontal landing method. Both the booster and orbiter use jet engines provided for landing the first stage in order to provide a safety measure (Figures 1 and 2).

The orbiter has a space called the cargo bay which can accomodate a payload 18.3 m long and 4.6 m in diameter. Besides its two crew members, the orbiter can carry twelve passengers.

The vehicles returned to the Earth will be inspected, serviced and used /9
again. At present, development is being carried out with the goal of reusing the craft more than 100 times in at least ten years.

FOLDOUT FRAME 1

TABLE 1. NASA ACTIVITY SCHEDULE.

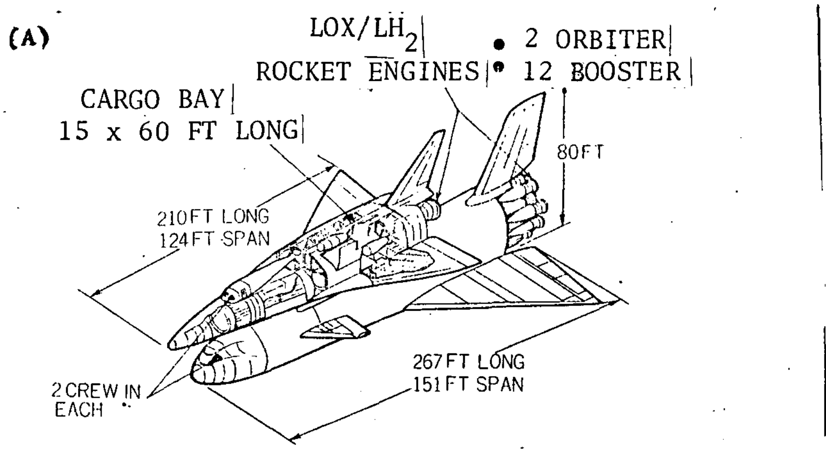
⊚ : Expected to start in 1972; ▽ : Expected to start after 1973; S: Space shuttle.

▼ : Started in 1971.

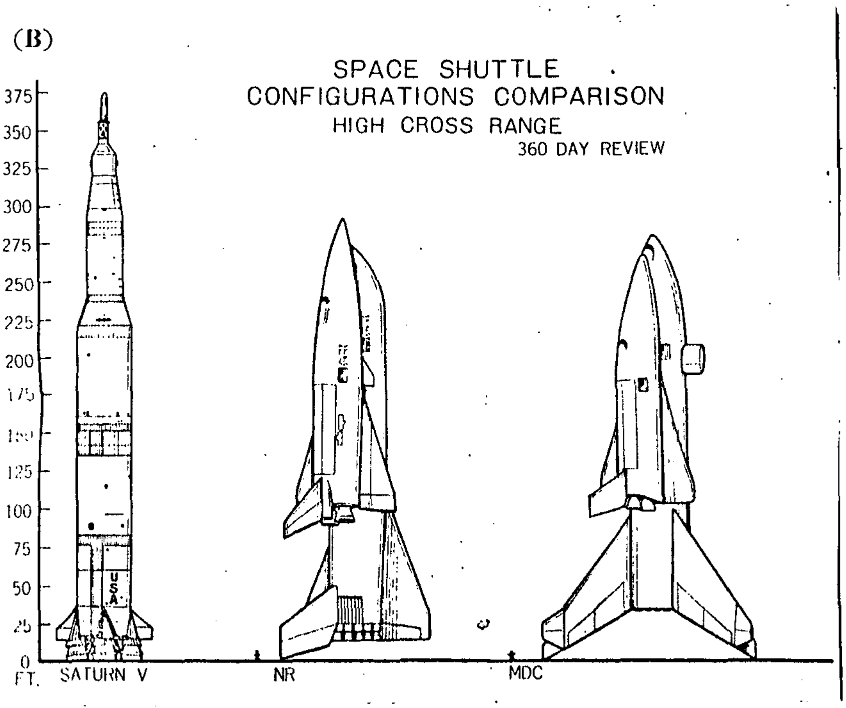
PROGRAM/PROJECT	VEHICLE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
ADVANCED CAPAB. DEVEL.														
SKYLAB	SAT & IB			▼										
SPACE SHUTTLE									FMOF ⊚	FUL ⊚	OPS			
SORTIE MODULE	S									S				
ORBITAL INJ. STAGE	S									S				
SPACE STATION	S											S		
LUNAR														
APOLLO	SAT V	14 15 ▼▼	16 17 ▼▼											
FOLLOW-ON EXPLOR.	OPEN													
PLANETARY														
MERCURY														
MARINER VEN. MERC. '73	ATL/CENT			J▼										
VENUS														
EXPLORERS	DELTA S						▽	▽	▽			S		
MARS														
MARINER ORBITERS '71	ATL/CENT	H I ▼▼												
VIKING	T IIID/CENT					A B ▼▼				▽		▽		
COMETS/ASTEROIDS														
RENDEZVOUS														
OUTER PLANETS														
JUPITER PIONEER	ATL/CENT		F ▼	G ▼										
JUPITER 'TOPS' ORB. S	T IIID/C											S		
GRAND TOUR	T IIID/CENT						T ⊚	T ⊚		JUN ⊚ ⊚				
INTERPLANETARY														
HELIOS	T IIID/CENT				▼	▼								
ADVANCED RES. & TECH.														
SPACE RES. & TECH.														
METEOROID TECH. SAT.	SCOUT		▼								S_2	S	S_2	S
SORTIES	S													
LABS & MODULES	S													
SPACE PHYSICS														
ATMOS. EXPLORERS	DELTA			C ▼	D ▼	E ▼								
ISIS	DELTA	B▼												
IMP	DELTA	I ▼	H▼	J▼										
DUAL AIR DENSITY	SCOUT				▼▼									
COOPS	SCOUT	G. SMUK ▼▼▼												
SSS	SCOUT	A▼												
RELATIVITY EXPER.	T IIID S											S		
FOLLOW-ON EXPLORERS	DEL/SCT S					▽▽	▽▽▽	▽▽▽	▽▽▽	S_3	S_3	S_3	S_3	S_3
SORTIES	S									S	S	S	S_2	S
LABS & MODULES	S													S
ASTRONOMY														
STELLAR														
ORBITING OBSERV.	ATL/CENT		OAO C▼			SAS D▽			SAS E▽					
LST	S											S		
SOLAR														
SOLAR ORBIT PAIR	S													S'84
OSO	DELTA	H ▼		I ▼	J ▼		K ▼		▽		▽			S
ATM	SKYLAB			▼										
LSO	S													S
HIGH ENERGY														
HEAO	T IIID/CS					⊚	⊚			S			S	
EXPLORERS	DEL/SCT	▼▼	▼▼	▼	▼									
RADIO														
INTERFER. TELES.	S												S	
~~LGE RADIO OBSERV.~~	~~S~~													~~S'85~~
GENERAL														
EXPLORERS	DEL/SCTS					▽▽	▽▽	▽▽	▽▽	S_2	S_2	S_2	S_2	S_2
SORTIES	S									S	S	S_2	S_3	S_4
LABS & MODULES	S													
SPACE APPLICATIONS														
R & D														
COMM. & NAVIGATION														
ATS	S T IIIC			F▼		G▼		▽	▽	▽		S		S
CAS	DEL/SCT S	▼			▽			▽		S			S	
SATS	DEL/SCT S					▽	▽▽	▽▽	▽▽	▽▽	S_2	S_2	S_2	S_2
SORTIES	S											S	S	
LABS & MODULES	S													S
EARTH OBSERVATIONS														
NIMBUS	DELTA		▼E		▼F									
ERTS	DELTA		▼A	▼B										
EOS	DELTA S					▽	▽	▽	▽	▽	S	S	S	S
SEOS	DELTA S								▽		S		S	
EPS	S											S	S	S
SORTIES	S										S	S_2	S_2	S_2
LABS & MODULES	S											S		
SYSTEMS DEMO. S C														
COMM. & NAVIGATION														
DATA RELAY	T IIID/CENT						▽▽							
PLANETARY RELAY	DELTA								▽▽					
MEDICAL NETWORK	S									S_2				
EDUC. BROADCAST	S										S_2			
FOLLOW-ON COMM.	S											S_2	S_2	S_2
EARTH OBSERVATIONS														
SMS	DELTA S		▼A	▼B				▽		▽			S	S
TIROS	T IIIB S						▽					S		
POLAR ERS	T IIIC						▽	▽▽	▽					
SYNCH. ERS	S											S	S_2	S
LIFE SCIENCES														
BIO. MODULES	SCOUT					▽	▽	▽	▽					
SORTIES	S									S	S	S		
LABS & MODULES	S											S		

FOLDOUT FRAME 2

(Source: TRW)



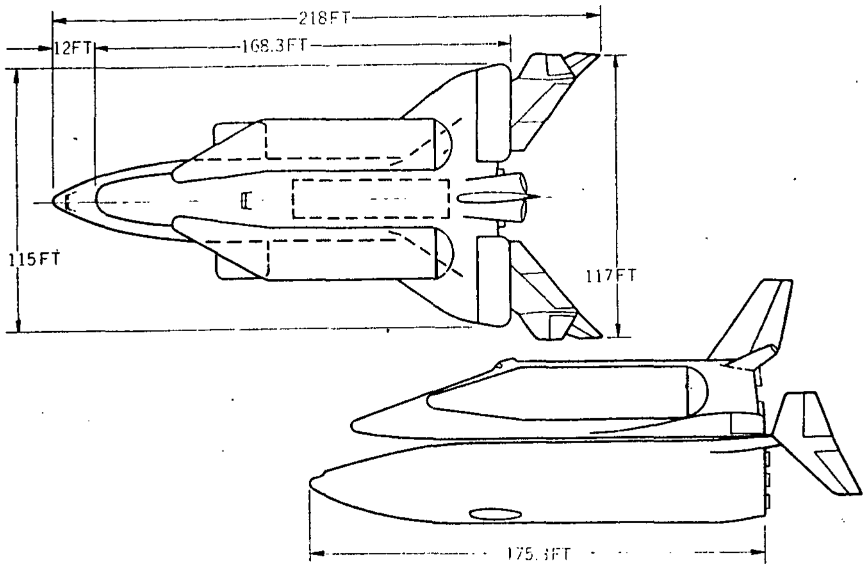
(Source: North American Rockwell)



(Source: NASA)

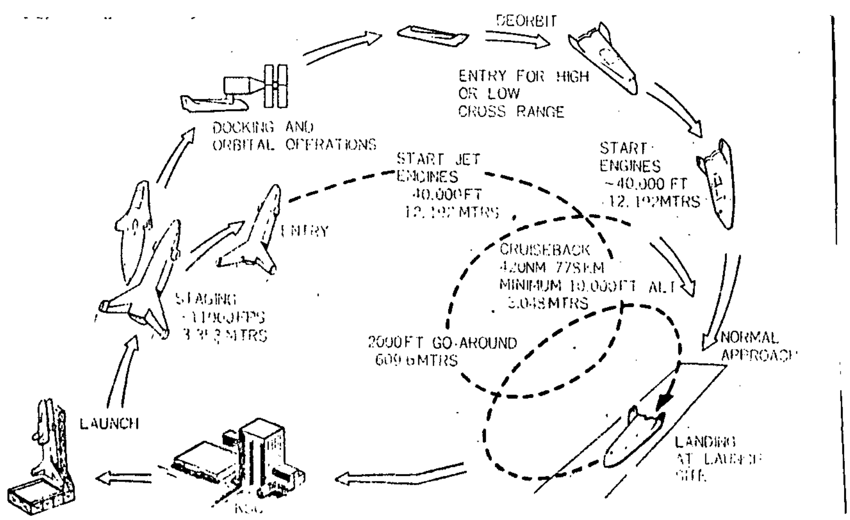
Figure 1. Sketch of a Space Shuttle.

(C) EXTERNAL LH2 TANK SYSTEM



(Source: McDonnell Douglas)

Figure 1 (Continued)



(Source: Lockheed)

Figure 2. Outline of Space Shuttle Launch.

(2) Economic Characteristics

The economic characteristics of the space shuttle are as follows:

First, the launching and mission costs are low. This is due to 1) the reusability of the vehicles, 2) the multiple purpose usage of the vehicles which eliminates the need of making many different types of rockets and 3) the presence of the crew members, which makes the recovery of the vehicles much simpler.

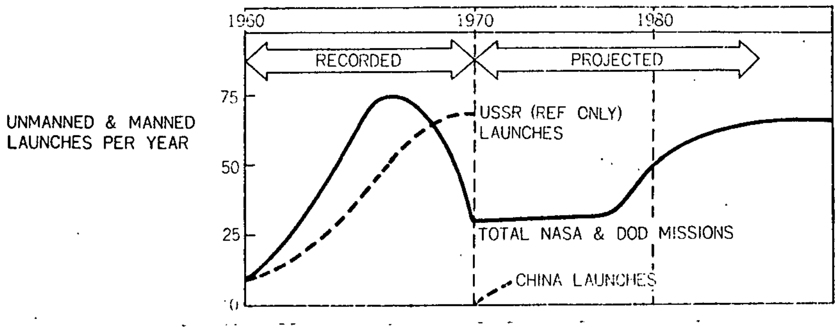
Second, the cost of the payload is cheap. This is due to 1) the large payload capacity of the shuttle which eases the restrictions imposed of the volume and weight in the payload design so that it is not necessary to complicate the payload itself excessively, 2) the possibility of reusing or regenerating the payload since it is possible to inspect and service satellites in orbit or return them to the ground by means of the shuttle and 3) the safe return of the shuttle if something goes wrong, which eliminates the possibility of wasting the entire payload, as used to be the case when the rocket was crippled.

According to present calculations, the cost per pound of payload comes out to be approximately $100, which is about one-tenth of the current minimum cost (Table 2). Figures 3 and 4 show how much can be saved by using the space shuttle.

TABLE 2. COMPARISON OF LAUNCH COSTS.

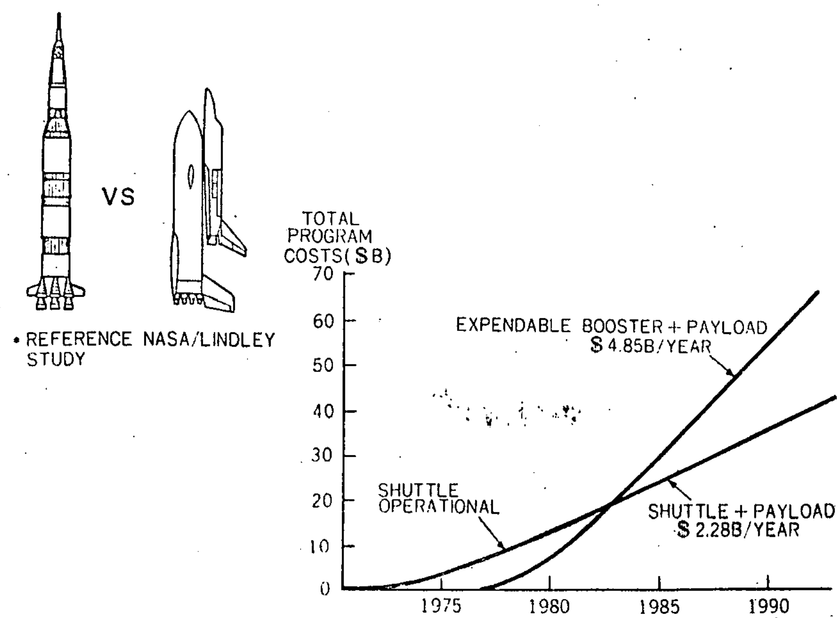
	THOR DELTA	ATLAS CENTAUR	TITAN 3C	SATURN 5	SHUTTLE
LAUNCH COST	500(万ドル)	1,500	2,400	22,500	500
PAYLOAD 100NM DUE EAST	2,600(Lbs)	11,400	26,000	285,000	65,000
$/LB TO ORBIT	1,900(ドル)	1,300	900	800	75

(Source: NASA)



(Source: North American Rockwell)

Figure 3. Number of Satellite Launches in the U. S. A.



(Source: North American Rockwell)

Figure 4. Comparison of Launch Costs Between Current and Shuttle Methods.

(3) Fields of Application /11

Various applications of the shuttles can be developed by utilizing the characteristics of the large payload capacity and the reusability. The following list shows several of them (Figure 5).

a. Use for short-duration scientific research activities and applications,

b. Inspection, service and recovery of artificial satellites in orbit,

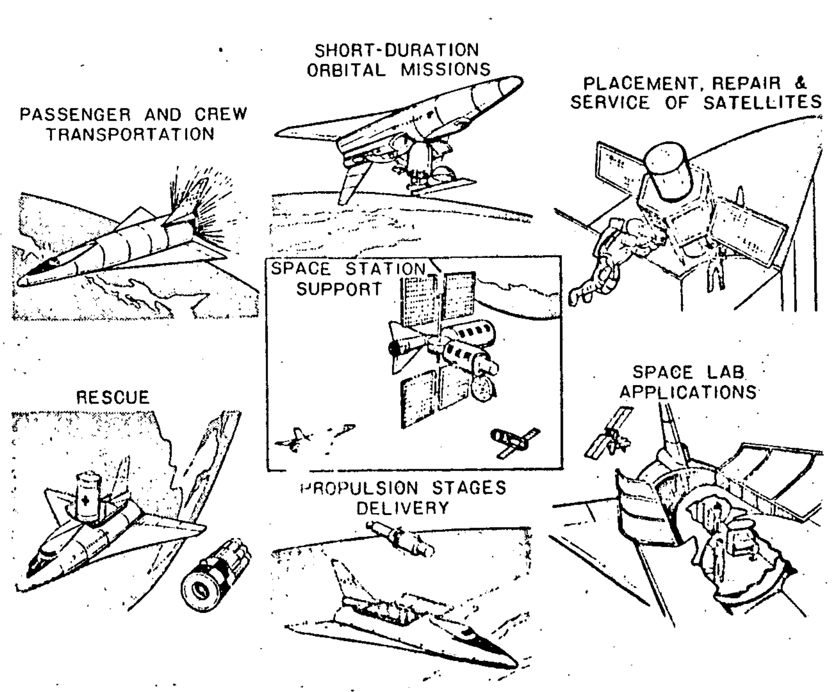
c. Placement of artificial satellites in orbit,

d. Rescue of spacecraft,

e. Transporation and supply of personnel and instruments to space stations,

f. Transportation of a space tug and its fuel supply,

g. Use as a launching platform for a spacecraft for planetary exploration.



(Source: NASA)

Figure 5.

(4) <u>Design</u> 712

The basic design of the space shuttle is a two-stage fully reusable type. During the recent year of Phase B study, various configurations have been developed (Table 3). As of now, the following items are the basis of the design.

① Fully reusable

② Cross range (Delta wing orbiter) : 1,100 N.M.

③ Cargo Bay : 15 Ft/D × 60 Ft/L

④ Payload : 65,000 Lbs in due east orbit
40,000 Lbs landed

⑤ All azimuth launch

⑥ Intact abort

⑦ Mission duration : 7 days with full payload

⑧ Fly back to launch site capability

⑨ Go around capability (2,000 Ft)

⑩ Main engine : 550,000 Lbs thrust LH_2/LOX

⑪ Cruise engine : JP/Air breathing

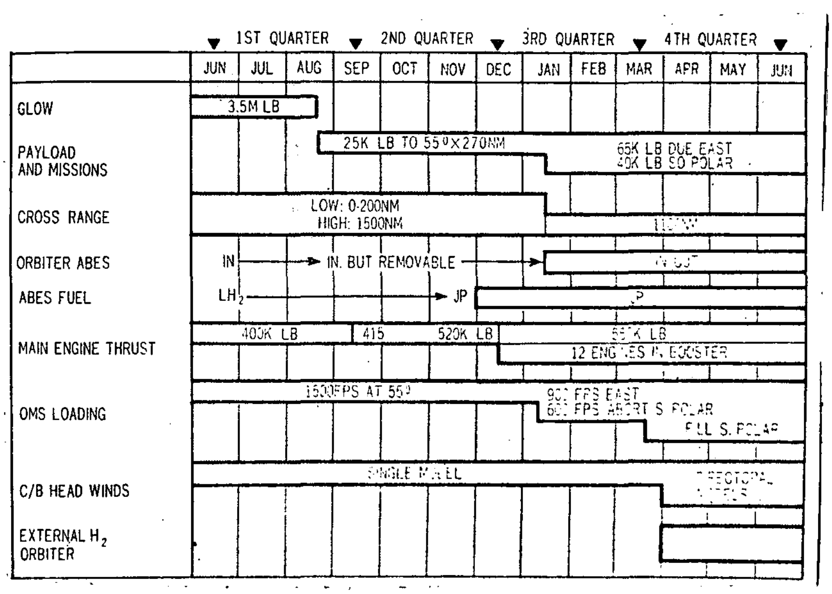
⑫ Shirt-sleeve environment for crew and passengers

Besides the two-stage fully reusable (reusable booster/reusable orbiter) type, the following designs are also being studied as alternatives (Figure 6).

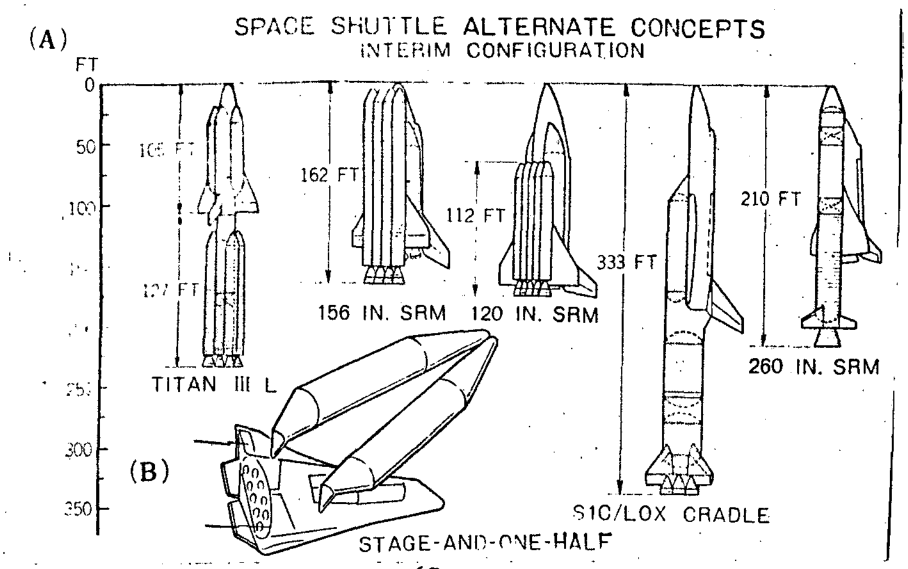
•Semi-reusable (S-IC/Reusable orbiter, Solid fuel rocket booster/Reusable orbiter) or

•Fractional stages (stage-and-one-half)

TABLE 3. CHANGES IN SPACE SHUTTLE REQUIREMENTS.



(Source: McDonnell Douglas)



(Source: NASA and Lockheed)

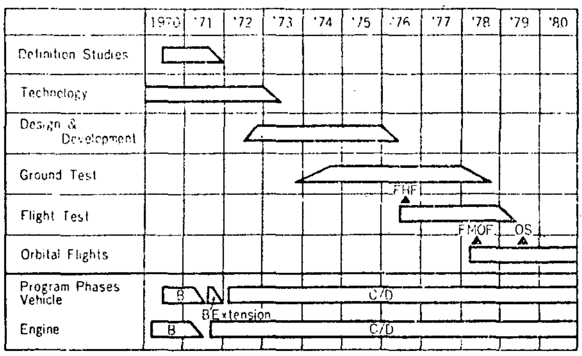
Figure 6. Examples of Alternate Space Shuttle Concepts.

(5) Development Schedule /14

The table below shows a master schedule of space shuttle development.

TABLE 4. DEVELOPMENT SCHEDULE OF SPACE SHUTTLE.

(A)

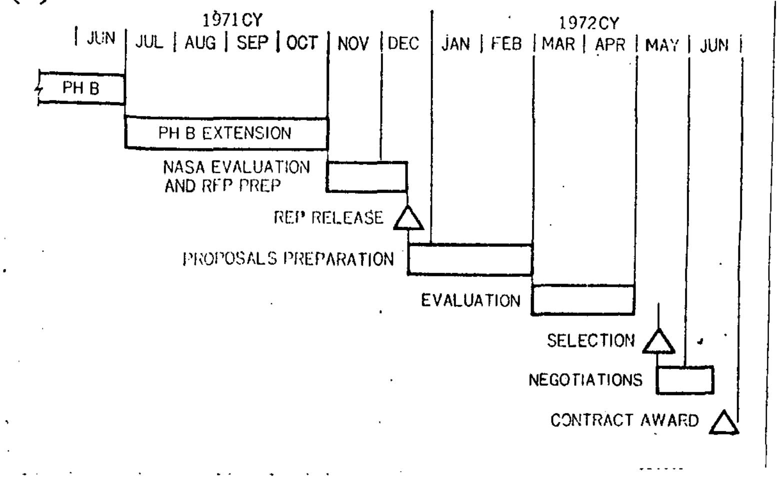


FHF : First Horizontal Flight
FMOF : First Manned Orbital Flight
OS : Operational Shuttle

(Source: NASA)

TABLE 4 (Continued)

(B)



(Source: NASA)

(6) Current Status of Development /15

a. Vehicle (or body) The Phase B study of the space shuttle body lasted from the middle of 1970 to the end of June, 1971. At present, the Phase B extension is in progress with the completion target date of October 1971. The purpose of this extension is to study further the alternate concepts of orbiter design, the intermediate concept which uses the conventional booster and the reusable booster. The major items in the study are as follows.

For the system
- Size and weight of the payload
- Abort
- Locking
- Staging velocities

For the orbiter
- Position of tank
- Type and number of engines
- Method of mounting jet engines
- Avionics

For the booster
- Size of the solid fuel engine, if the conventional type is used.
- Types of liquid fuel rockets
- Carnot type

When this Phase B extension is completed, a series of tasks such as evaluation by NASA, writing of an RFP (Request for Proposal) and the submission and evaluation of the proposals will be carried out. By May of next year (1972), the tasks will be complete and it is expected that Phase C/D contracts will be awarded in June (Table 5).

b. Contacts /16

Three teams are involved in the Phase B study of the space shuttle (Table 5).

TABLE 5.

	Prime	McDonnell Douglas	North American Rockwell (Space Div.)	Grumman/Boeing
U.S.A. (Company)		Martin Marietta	General Dynamics (Convair Div.)	Northrop
		TRW	General Electric (Thermal Protection System)	Aerojet-General
				General Electric (Avionics)
		Sperry	Honeywell	
		Hamilton Standard	IBM	AVCO
		Raytheon		
		Pan American Airline	American Airline	Eastern Airline
		Norden Div. of UAC		
Foreign company	UK	Hawker Siddeley	BAC	
	France	SNIAS	Thomson CSF	Dassault
	Germany	ERNO	MBB	Dornier
	Italy		Fiat	
Amount of contract U.S.A. co.		\$8 million	\$8 million	\$5.5 million
Under NASA		MSFC	MSC	

Besides this, there are two contracts to be awarded by NASA for Phase A study in order to investigate the various proposals submitted (Table 6).

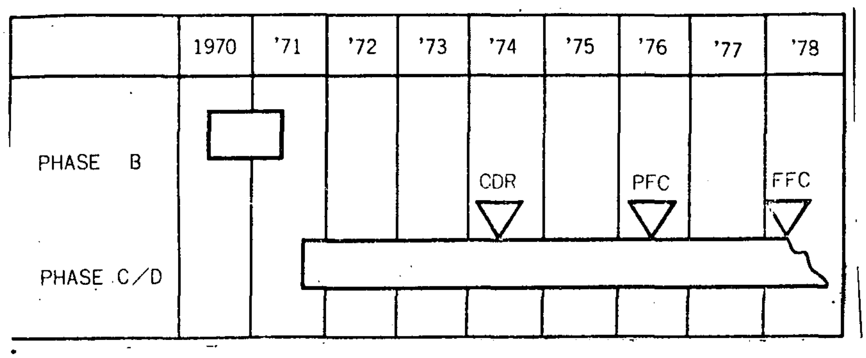
TABLE 6.

Company	Subject	Amount of contract
Lockheed Missile & Space Co.	"Stage-and-one-half" type vehicle	\$1.2 million
Chrysler Corp.	"Single stage-to-orbit" vehicle	\$ 750,000

c. Engine /17

Table 7 indicates the schedule of engine development for the space shuttle.

TABLE 7.



The main engine for the space shuttle is the responsibility of the Marshall Spaceflight Center, NASA. Since the middle of 1970, Phase B study has been conducted by three companies, P & W, Aerojet, and Rocketdyne with $6 million each. By the middle of last July, Rocketdyne had been selected as the contractor for Phase C/D. Its terms are to make thirty-six engines by 1978 and to receive $50 million as this year's share of the total amount of the contracts $500 million.

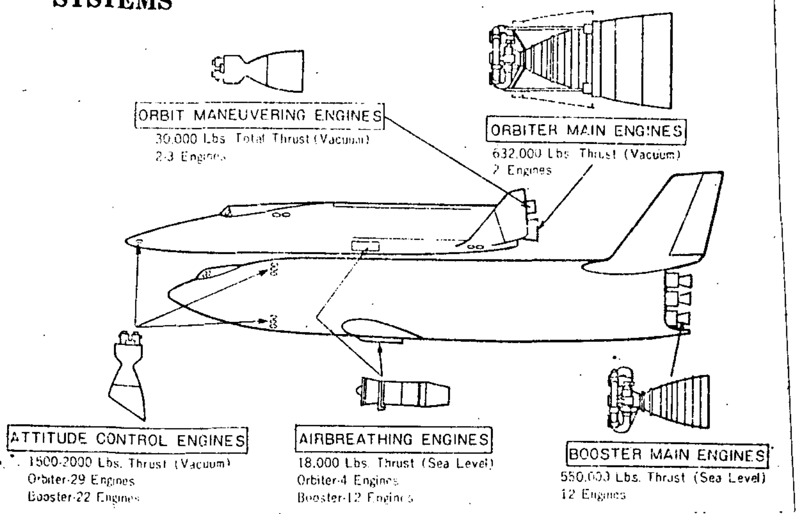
This engine would have a common "Powerhead" for both the booster and orbiter. However, an adequate nozzle will be attached to each of these (Figures 6 and 7).

The respective thrust and expansion ratio are as follows (Table 8).

TABLE 8.

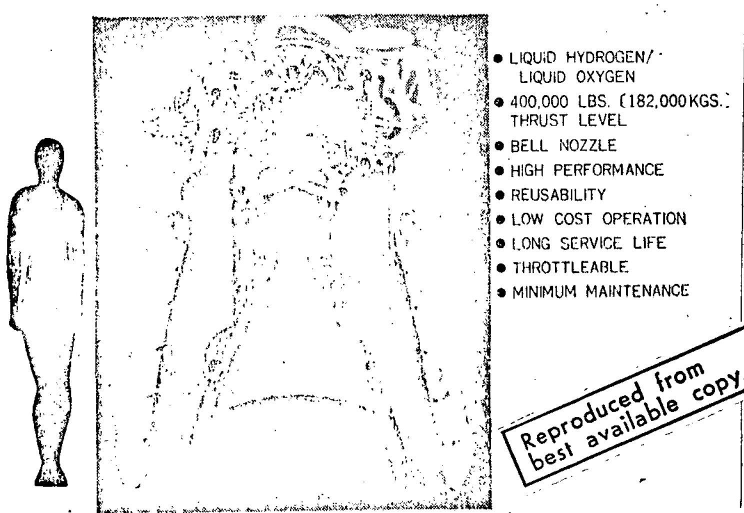
	Booster	Orbiter
Thrust	550,000 lbs (sea level)	632,000 lbs (vacuum)
Expansion rate	35:1	150:1

SPACE SHUTTLE BOOSTER AND ORBITER PROPULSIO[N] SYSTEMS



(Source: NASA)

Figure 6.



(Source: NASA)

Figure 7. Main Engine of Space Shuttle.

The engine is supported by a thimble and capable of vibrating up to 10° at the maximum.

For the auxiliary engines (APS), four research contracts are to be awarded. Their results show that the high-pressure turbo--pumped system is a strong candidate (Table 9). /19

(7) Development Cost

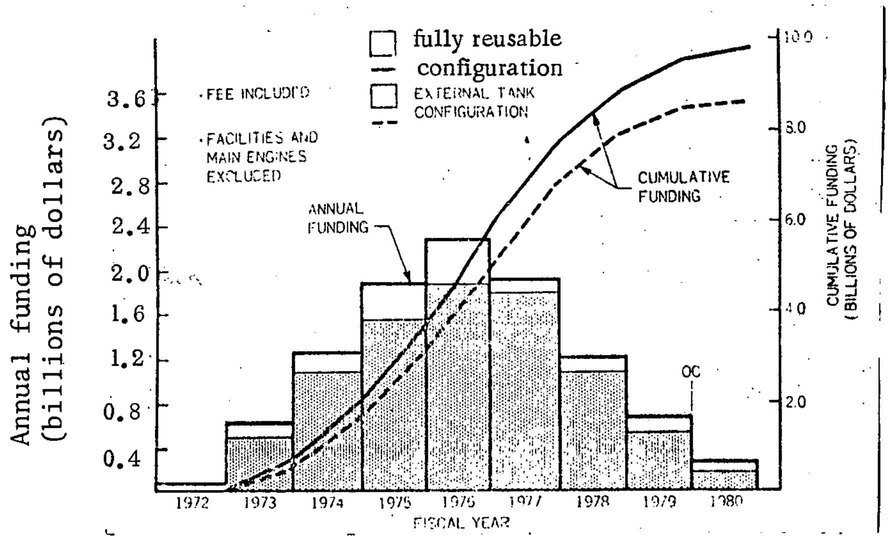
The annula development cost for the space shuttles (excluding main engines and facilities costs) is shown below (Figure 8).

(8) International Cooperation /20

For international cooperation in space shuttle development, there have been four international conferences between the U.S.A. and European countries between July 1970 and May 1971 at Lewis Research Center, Marshall Spaceflight Center and Manned Spacecraft Center. As a result, several companies in Europe have participated in the Phase B study as the subcontractors of the prime contractors in the U.S.A. (Table 10).

TABLE 9.

Engine types	Contractor	NASA center in charge	Amount of contract
High Pressure System (300Psi)	MDC	MSFC	$350,000
"	TRW	MSC	$250,000
Low Pressure System (20Psi)	MDC	MSC	$250,000
"	TRW	MSFC	$350,000



(Source: McDonnell Aircraft)

Figure 8.

The participation of these European companies is supported by European funds (governments and industries, on a deferred payment basis) in accordance with the basic principles of participation in the post-Apollo program (Figure 9). /21

NASA has the following policy regarding international participation after Phase B of the shuttle.

(1) The settlement (or decision) regarding technical assistance will be made at the end of the Phase B extension.

(2) The Phase C/D proposals are limited to U. S. contractors.

(3) A policy will be prepared for unofficial suggestions by foreign /22
companies.

(4) Until the Phase C/D contractors decide, there will be no settlement in the technical field.

TABLE 10.

Major contractor	Country	Company	Area of participation
MDC	United Kingdom	Hawker-Siddeley Dynamics	1. Flight mechanics aerodynamics 2. Thermodynamics 3. Structures 4. Avionics checkout 5. Propulsion
	France	SNIAS	1. Structures 2. Materials 3. Testing 4. Aerodynamics
	West Germany	ERNO	1. Aerodynamics 2. System integration 3. Thermodynamics 4. Avionics control 5. Structures

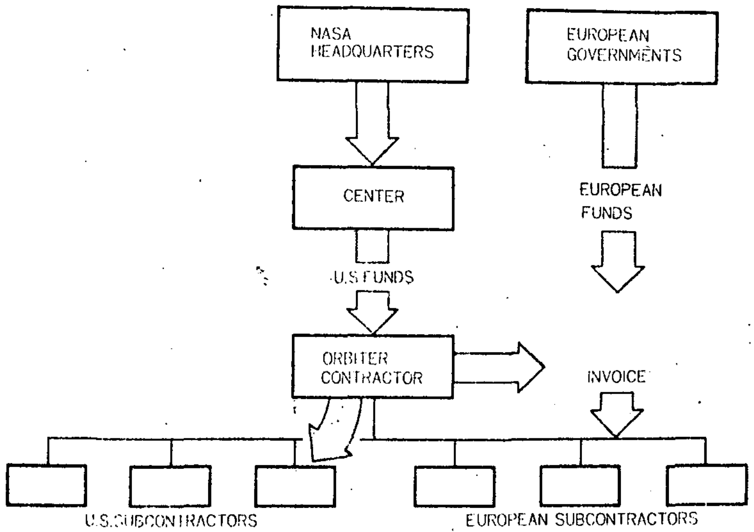
TABLE 10 (Continued)

Major contractor	Country	Company	Area of participation
NAR	United Kingdom	BAC	1. Structures 2. Avionics 3. Aerodynamics 4. European Missions
NAR	West Germany	MBB	1. Concept selection 2. Auxiliary propu'sion
NAR	France	Thomson CSF	Discussion
NAR	Italy	FIAT	Discussion
Grumman /Boeing	West Germany	Dornier	1. Insulation 2. Control Systems 3. ABEs 4. Materials
Grumman /Boeing	France	Dassault	1. Structures 2. Insulations 3. Separation

A common method for the participation of European companies is to send a relatively small team of technicians to the designated U. S. A. company, to work there and then to collect the information and prepare a final report in their own countries.

As an example, NAR (North American Rockwell) has six technicians sent by BAC (British Aircraft Corporation) from the United Kingdom. The primary benefit benefit to the foreign companies from participation is the gaining of technical information. For example, NAR offered up to 350 information references to BAC and 200 to MBB (Messerschmitt-Bolkow-Blohm) during a period of a little over one year since April 1970.

INTERNATIONAL LINES OF AUTHORITY



(Source: McDonnell Douglas)

Figure 9.

3. Space Station /23

(1) Outline

A space station is a semi-permanent space base placed in orbit around the Earth for long-term space activities such as research, experiments, observations or investigations in both pure and applied science.

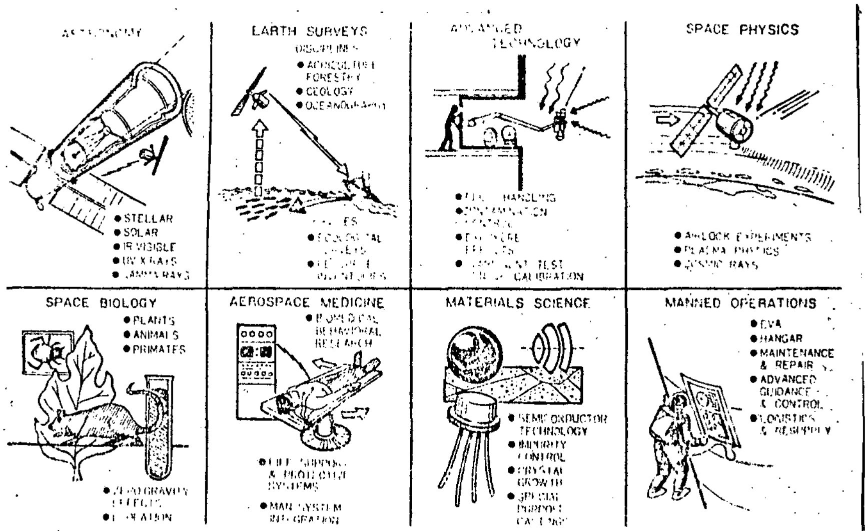
Due to its particular environment, a space station can be used to carry out many studies which may be impossible on the Earth, from astronomical observations, physical, medical and biological experiments to the survey of Earth resources and development of advanced technology. As the studies of these applications progress, it is thought that their application may be expanded beyond the limits of the imagination.

The space station program was initiated under the guidance of NASA and it is expected that the first launch will take place within ten years.

The fields of application of the space station are shown in Figure 10. /24

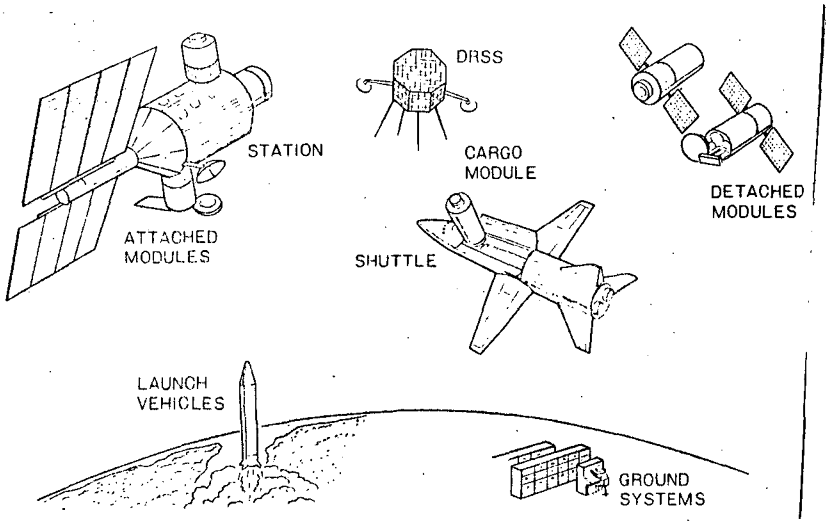
The space station program is a combined project consisting of the space station itself, a detached module orbiting near it, a space shuttle to transport crew members and materials between the Earth and the space station, the ground support system, data relay satellite and experimental plans (Figure 11).

The ground support system includes control, transportation of personnel and materials, collection and processing of data, experiments and operations.



(Source: NASA)

Figure 10. Examples of Space Station Applications.



(Source: NASA)

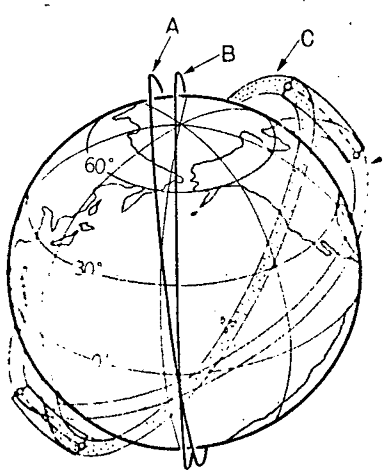
Figure 11.

Data transmission may be accomplished in several different ways. One is to collect data at the space station and transmit it to the Earth directly after appropriate conversion whenever necessary. Otherwise, the data may be stored and brought back to the Earth by a shuttle. In addition to these ways, it is also possible to launch a data-relay satellite and thus increase the real-time transmission ability which makes the experiments more effective.

Even though the experimental plan was formulated under the guidance of NASA, cooperation is expected from every possible institute and organization in world-wide academic, government and industrial circles. /25

As far as the experiments and observations of the space stations are concerned, they may be carried out not only in the space station itself and in the attached module but also in the detached module which may be moving along an orbit which is removed from the space station by as much as 2,800 nautical miles (N.M.) (approximately 5,200 km).

The orbit of a space station has an altitude of 200 ~ 300 N.M. (370 ~ 550 km) as shown in Figure 12. It is initially launched with an angle of inclination of 28.5° but the angle is later changed to 55°. For special missions, it may be on a polar orbit (90°) or a geostationary orbit (97°).



	ALTITUDE (nautical miles)	INCIDENCE ANGLE (degrees)
A	200	97
B	200	90
C	200-300	55
D	200-300	28.5

(Source: North American)

Figure 12.

(2) <u>Major Features of a Space Station</u> /26

There are two different concepts in the design of space stations, as will be described later, and it is hard to summarize the major features in general form. However, the capacities listed in Table 11 are basically required in the design.

TABLE 11. SPECIFICATIONS OF SPACE STATIONS.

Stability	Altitude Maintenance	$\leqslant 2.5°$ (0.1° in 30 min.)
	Angle change	$\leqslant 0.05°$/sec (0.01° in 30 min)
Acceleration	Normal (Passenger movement)	4×10^{-5} G
	Worst (docking of a shuttle)	0.035 G
	Periodical (displacement of solar battery panel)	2.5×10^{-4} G

	Station Mission	Experiments
Electric Power (total average for 24 hr = = 25 kW)	19 kW	6 kW
Amount of data		
Storage (2.5×10^6 words)	1.5×10^6 words	1×10^6 words
Data rate (180×10^9 bits/day)	22×10^9 bits/day	158×10^9 bits/day
Floor area (ft^2) 4,455	3,320 (including TOROIDS)	1,135
Capacity (ft^3) 26,478	17,460 (including TOROIDS)	7,700

(Source: NASA)

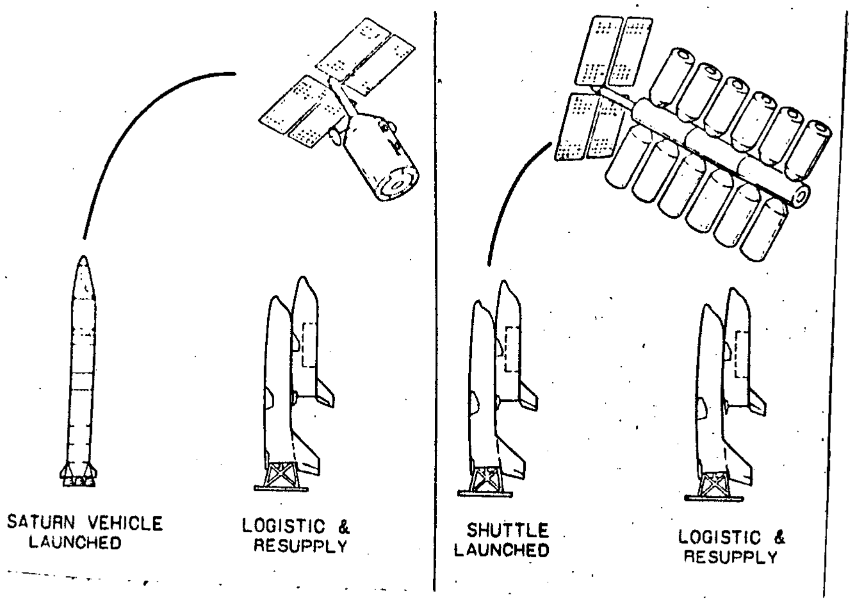
Besides, detailed studies have been made of the expendables (including oxygen and water). Whatever the specifications may be, the basic principle is to enable passengers to stay for a long period of time wearing ordinary clothes.

(3) Design of Space Station

The basic concepts of space station design are two: the conventional large-scale integral type and a modular type conceived later. At present, it is not /27
certain which type will be selected (Figure 13).

a. Large-Scale Space Station

This type measures 33 ft (approximately 9 m) in diameter and 50 ft (approximately 15 m) in length (excluding the solar battery panel) and is launched by means of a Saturn V rocket. There are twelve crew members and it is composed of four stages or decks as well as upper and lower toroids. If necessary, up to four attached modules (A.M.) can be docked at the station (Figures 14 through 18).



(Source: NASA)

Figure 13. Comparison of Space Station Shapes.

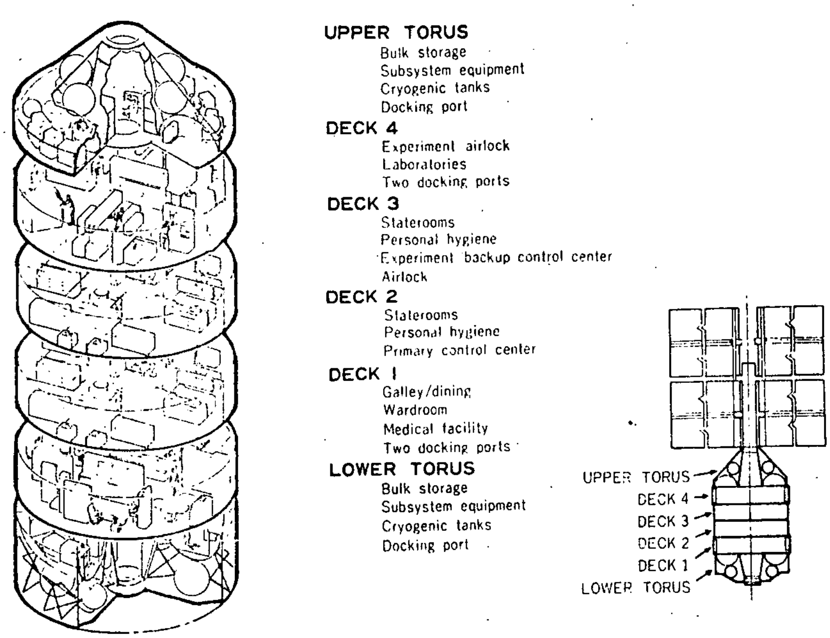
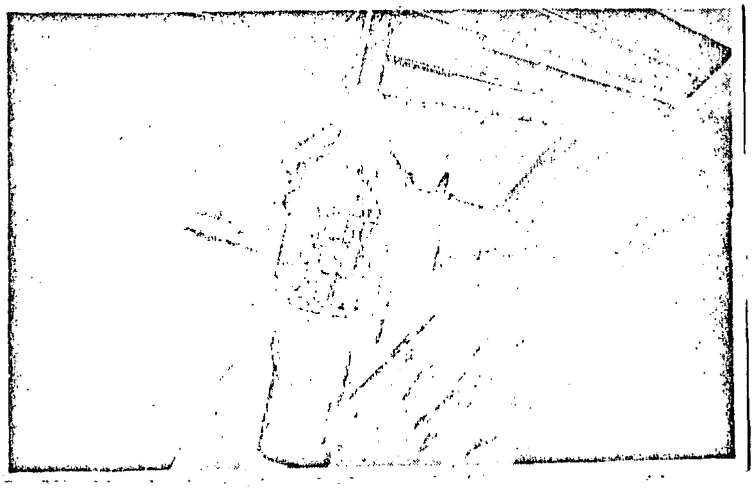


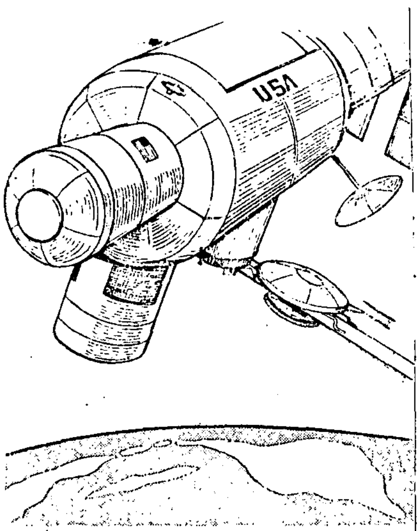
Figure 14.

(Source: North American Rockwell)



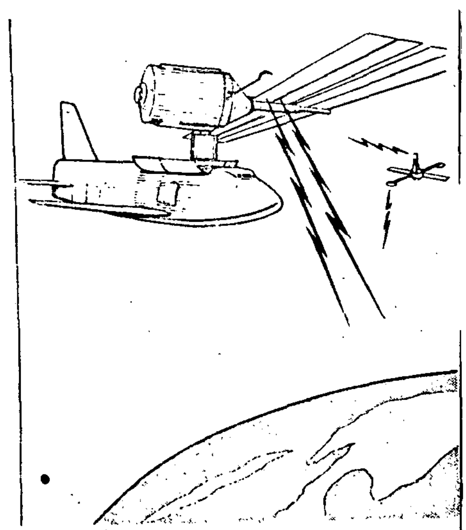
(Source: NASA)

Figure 15.



(Source: North American Rockwell)

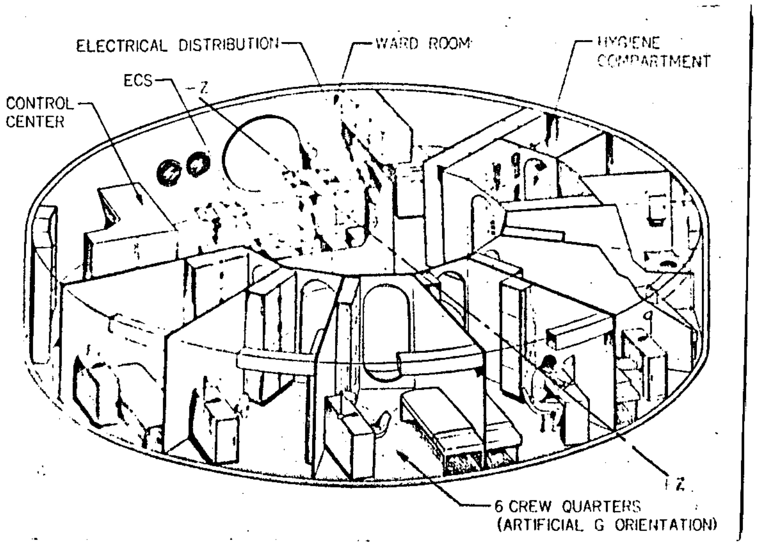
Figure 16.



(Source: North American Rockwell)

Figure 17.

This type of space station would have a lifetime of approximately ten years but recovery is impossible. All the expendables (enough for a half-year) will be loaded at the start. The exchange of crew members, supply of materials as well as docking the attached module will be carried out by use of space shuttles.



(Source: NASA)

Figure 18. Living Quarters in Space Station (Decks 1 and 3).

b. Modular Type of Space Station /30

This type is 14 ft (approximately 4.3 m) in diameter and less than 58 ft (approximately 17.7 m) in length. This station is constructed by assembling modules which weigh less than 20,000 lbs each (approximately 9 tons). This size can be accommodated in the cargo bay of a space shuttle). Most of the materials will be launched by means of a space shuttle. It is also possible to recover the station if necessary. Initially there will be six crew members, but this can be increased to twelve by adding more modules (Figure 19).

The basic module types are as shown in Figure 20:

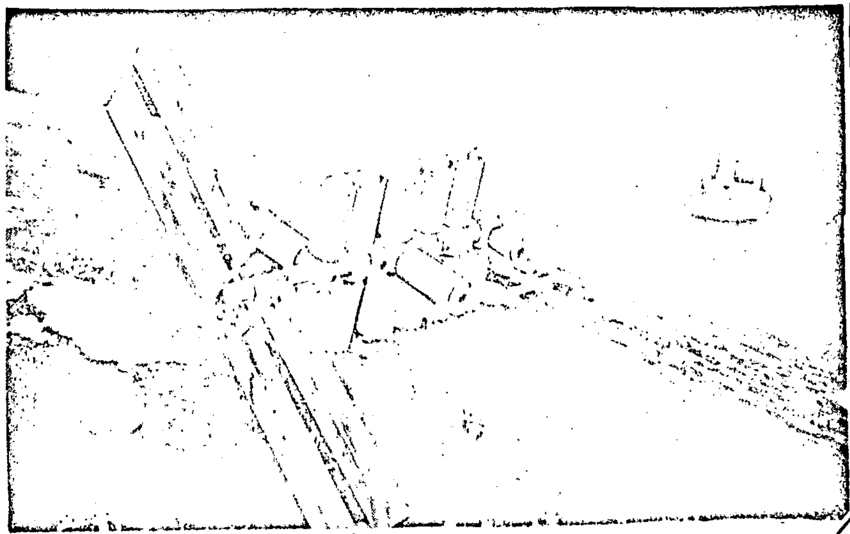
(a) Standardized module,

(b) Electrical power module, and

(c) Central core module.

In order to assemble these modules, structually and organizationally, common parts are used as much as possible. /31

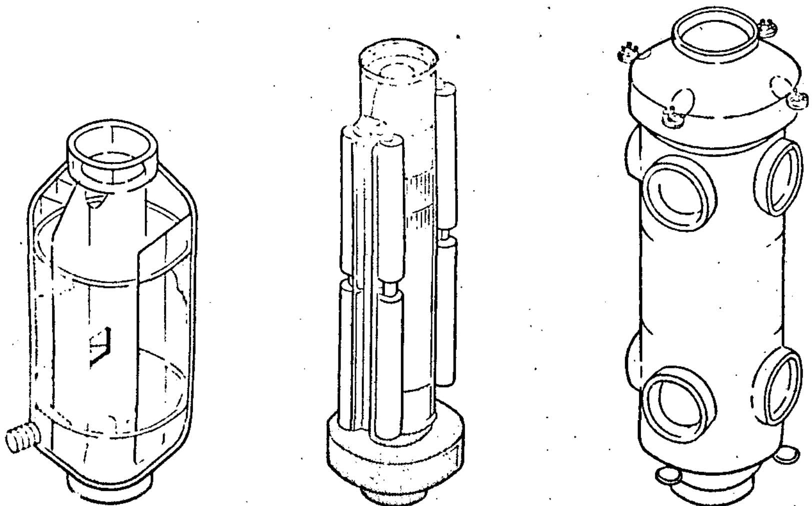
The purpose of each module is given in Table 12.



(Source: NASA)

Figure 19.

SPACE STATION MODULAR BUILDING ELEMENTS



(Source: NASA)

Figure 20.

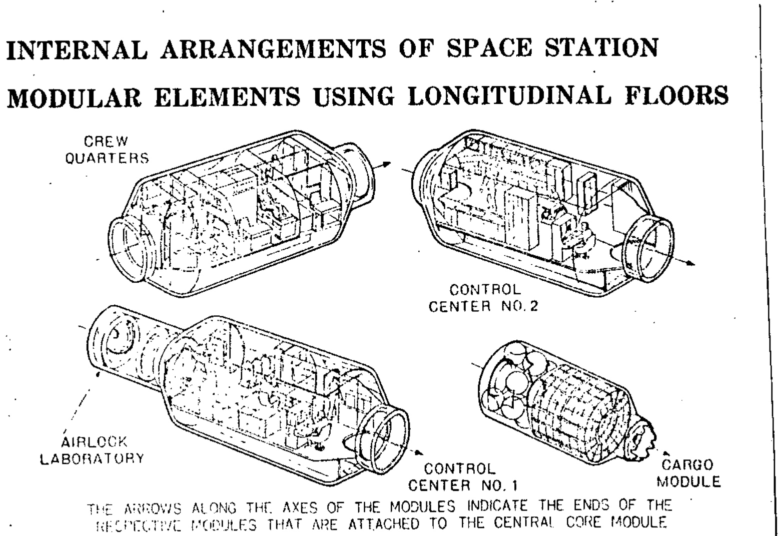
TABLE 12.

Space Station Modules	Modules for Experiments	
Crew living quarters (10 ~ 15) Control Center (20) Central Core Module (20) Electrical Power Module (17 ~ 20)	Earth Survey Module General purpose laboratory Free Flight Module	(12 ~ 20)

Note: Numbers indicate approximate weights (lb × 10^3)

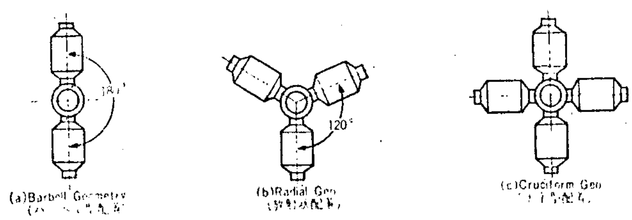
A typical example is given in Figure 21.

There are three fundamental ways of assembling the modules as shown in /32
Figure 22. Some examples are given in Figures 23 through 25.



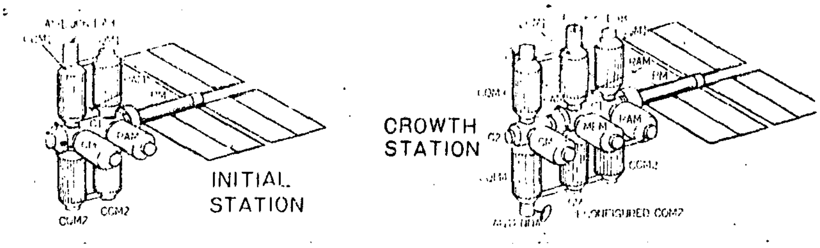
(Source: NASA)

Figure 21.



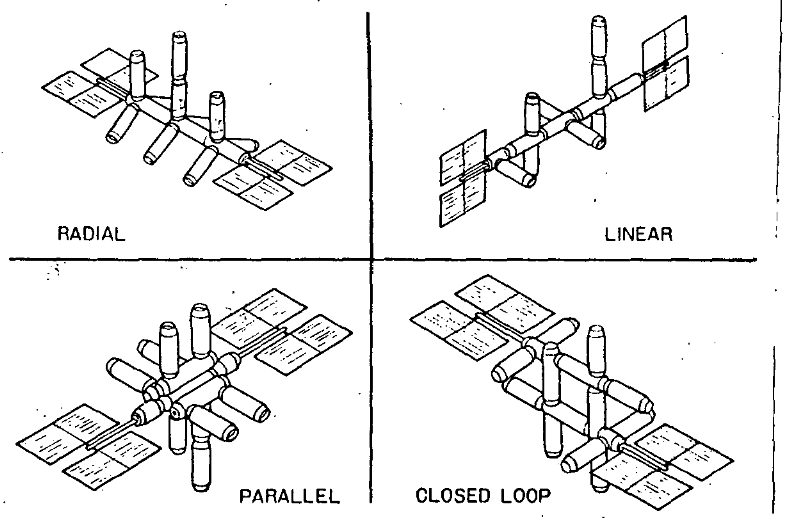
(Source: NASA)

Figure 22. Fundamental Types of Module Assembly.



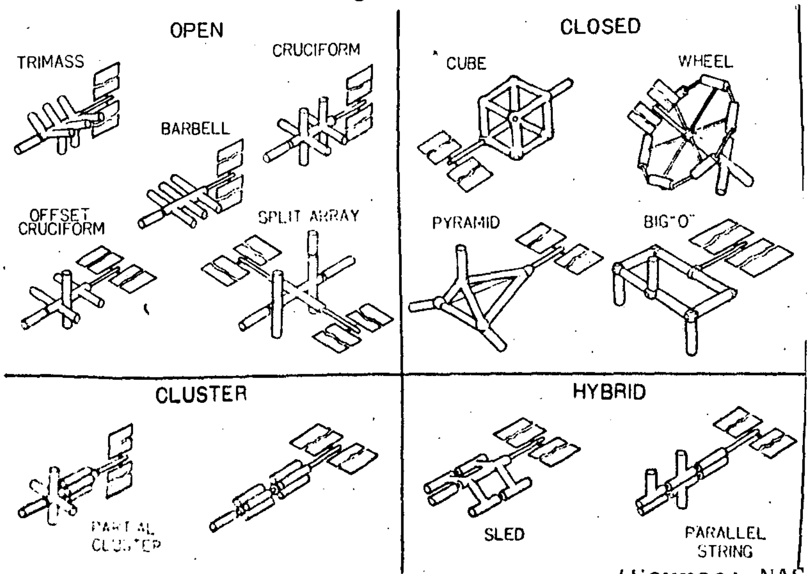
(Source: NASA)

Figure 23. Examples of Module Assembly.



(Source: NASA)

Figure 24.



(Source: NASA)

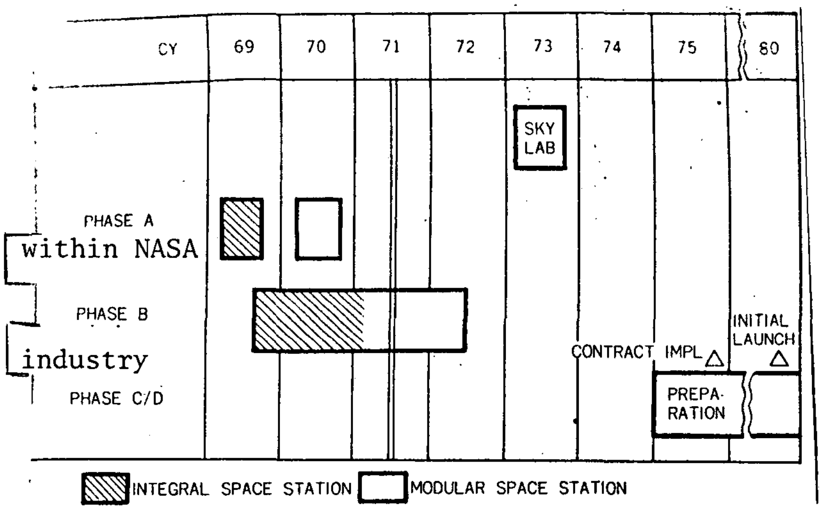
Figure 25.

(4) Current Status of Development /34

A schedule of space station development is shown in Table 13.

In the latter part of 1968, when the idea of a space shuttle was still indefinite, a large-scale station which could be launched by use of a Saturn V was conceived. The internal study on this by NASA was concluded by the summer of 1969. From September of the same year to July, 1970, a definition study of the system configuration and program plans was completed with McDonnell Douglas and North American Rockwell as prime contractors (Table 14).

TABLE 13. A SCHEDULE OF SPACE STATION DEVELOPMENT.



(Source: NASA)

On the other hand, as the concept of the space shuttle became clearer, it was known that the launch cost could be greatly reduced if this were used. In early 1970, NASA completed its internal investigation of the module-type station which can be launched and recovered by means of a space shuttle. At present, the Phase A study is being carried out by the above two companies as contractors.

Concerning these two measures, not only on-paper studies but also studies using mock-ups and development of a partial critical subsystem are under way.

TABLE 14.

McDonnell Douglas Group	North American Rockwell Group
Martin Marietta	G E
I BM	General Motors
Hamilton Standard	Garrett Corp.
Collins Radio Company	Atomics International
Bendix Corp.	Eliot Noyes and Associates
Atomics International Division/NARC	United Aircraft
Minneapolis Honeywell	Marquardt Corp.
Philco-Ford	Sundstrand Aviation
Comsat	Whirlpool Corp.
Others	Others

An attempt is also being made to use common parts in the Skylab and space shuttle as much as possible. The airlock of a Skylab and the RAM (Research and Applications Module) which can be used in a space shuttle for short-duration experiments (less than seven days) are good examples. The following figure shows the flow of development (Figure 26).

On the topic of applications of space stations, the first conference was held at the NASA Ames Research Center in September 1970, attended by approximately 450 people from the U. S. A. and abroad. At that conference, NASA indicated its plans and programs for the applications of space stations. /36

Since then, there have been meetings at universities in Pittsburgh, Berkeley, Atlanta and Wichita, attended by approximately fifty persons each from January to February of this year, in order to get inputs from the utilization organizations and to exchange ideas, which may be another indication of the open-door attitude of NASA.

(5) International Cooperation

As mentioned in the previous section, ideas are being gathered internationally on the applications of the space stations. Also, the items for observation and experiment are not determined solely by NASA but require co-operation of academic societies. General information on this may be obtained from NASA Headquarters, while technical information can be obtained from the Manned Spacecraft Center[2]

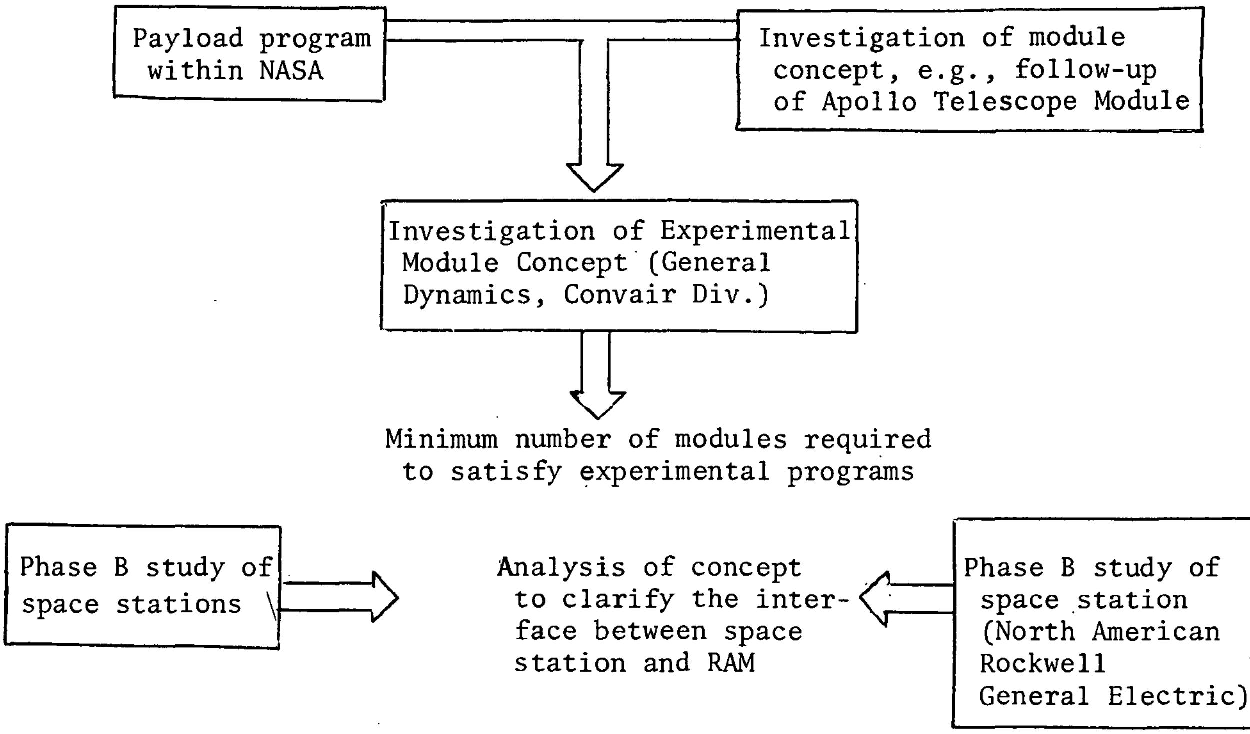
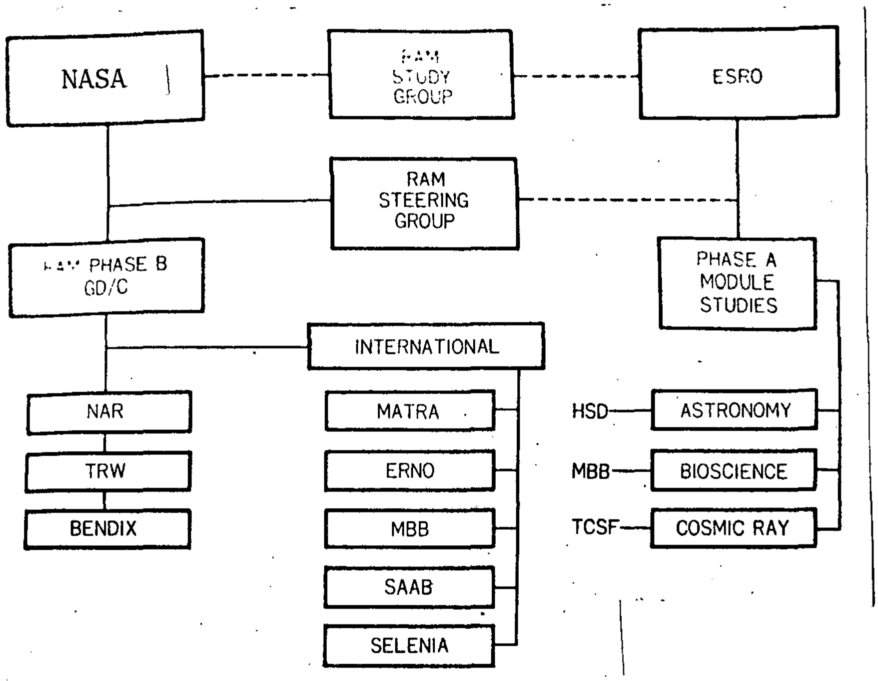


Figure 26. Background of RAM.

Although there is no space shuttle-type cooperation for the space station, European companies are cooperating with General Dynamics (Convair Division) on the RAM and ESRO is participating in the experimental module studies.

[2]Note: NASA Headquarters: Mr. S. H. Hubbard, MF, NASA HQ., Washington, D. C. 20546 and MSC: Mr. C. M. Grant, Jr., BM2, NASA, Manned Spacecraft Center, Houston, Texas 77058.

The launch is scheduled for 1977. Several flight techniques, such as free flight, flight by combining with an Apollo Command Module and flight by combining with a Space Shuttle are under consideration.



(Source: NASA)

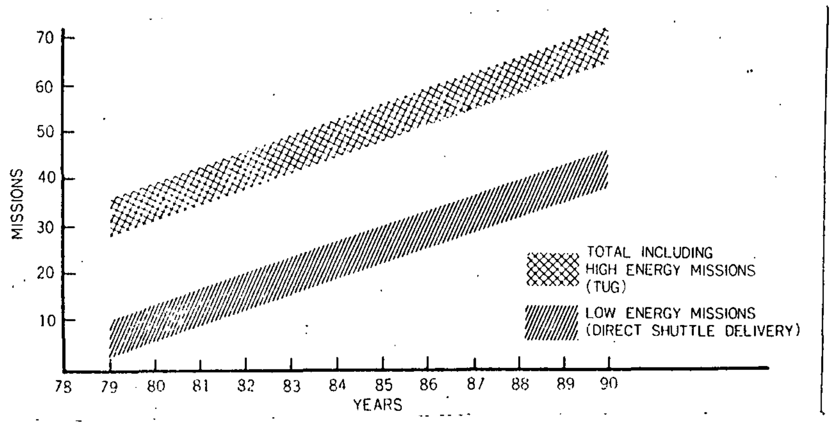
Figure 27. Status of International Cooperation.

4. Space Tug /38

(1) Outline

The space tug is being developed as a new means of space transportation for the 1980s, which will be used in connection with the space shuttle. For many space objects such as the artificial satellites and spacecraft expected to be launched in 1979 to 1990, the space shuttle alone does not have sufficient energy for launching them, and a tug is necessary as the third stage of the shuttle (Figure 28).

The number of missions for different applications is given in Figure 29. Here, a tug is used in the orbit-to-orbit shuttle and for retrieval. It is conjectured that approximately 60% of the missions are NASA-related and 40% are DOD-related. It is also estimated that approximately 70% are for geostationary orbits and others are for medium to high orbits and interplanetary flights.



(Source: NASA)

Figure 28. NASA Missions and Required Energy Estimates.

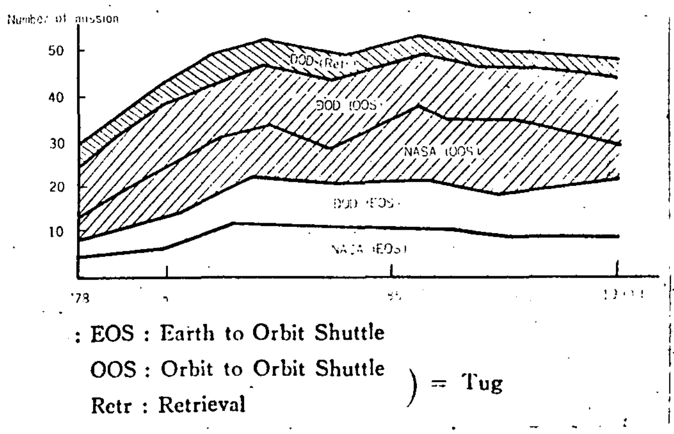


Figure 29. Expected Number of Missions for Each Application.

Figure 30 shows the relationship between the payload of the space shuttle and the altitude of a circular orbit, while Figure 31 shows the relationship between the missions and orbit altitudes.

Summarizing these, a shuttle — tug assembly for the NASA missions only is shown in Figure 32. In particular, the placement of a satellite in a geosynchronous orbit is shown in Figure 33. /39

(2) <u>Basic Concept of Space Tug</u> /41

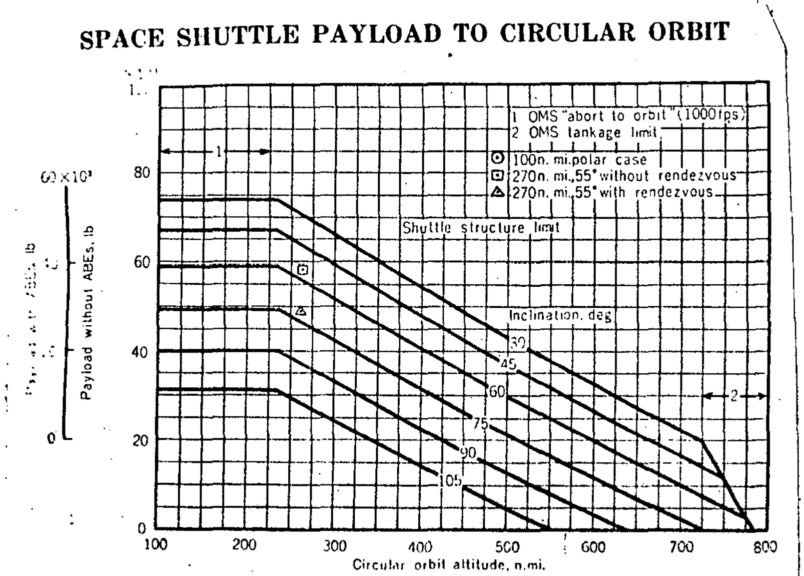
The role of a space tug in the post-Apollo space transportation system is very important since it is a space system which has a very wide range of applications and can be used for many purposes. The features a tug should have are as follows:

a. It should be able to remove a satellite from a shuttle to place it in orbit and conversely to recover a satellite and place it aboard a shuttle.

b. It should be able to place an interplanetary spacecraft on an escape trajectory.

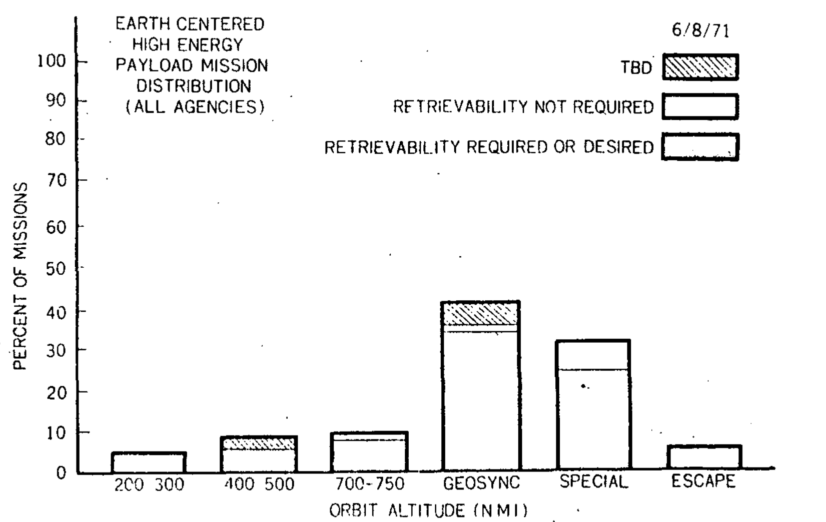
c. It should be able to do various operations such as in-orbit exchange of cargo and attaching cargo to the space station.

d. It should be able to supply and support various systems in orbit.



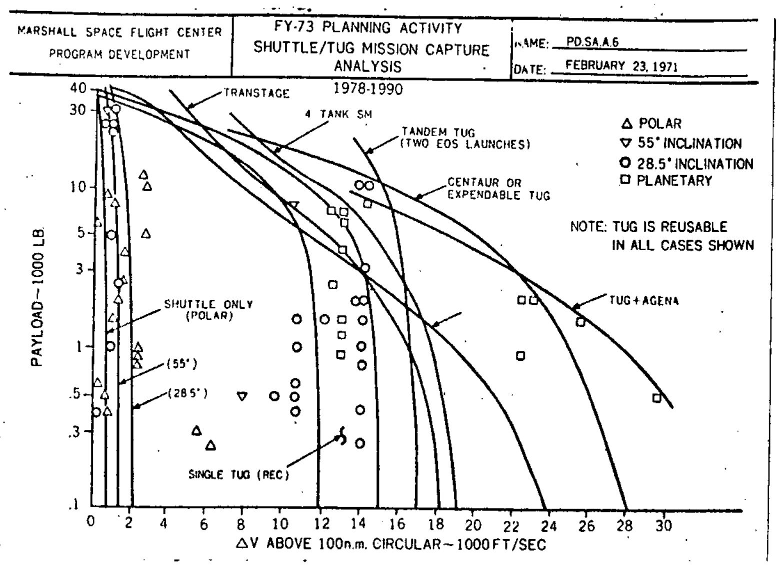
(Source: NASA)

Figure 30.



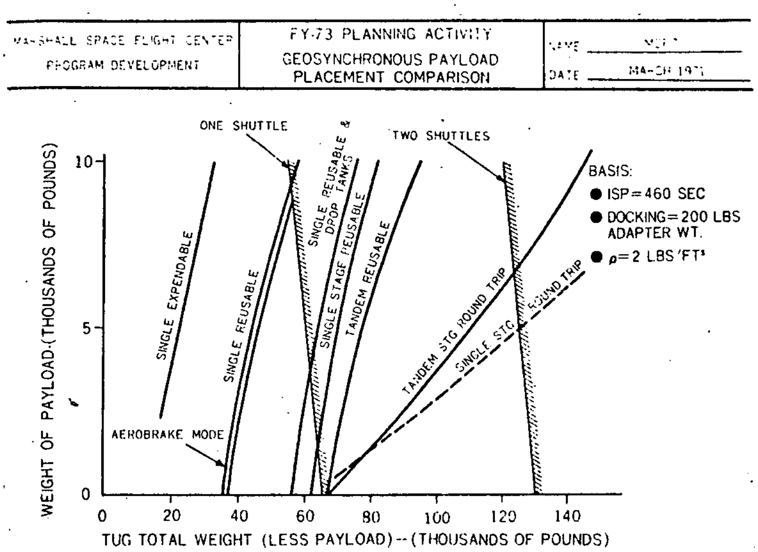
(Source: NASA)

Figure 31.



(Source: NASA)

Figure 32.



(Source: NASA)

Figure 33.

(3) Technical Problems

Technical problems considered in space tug development are listed below. /42

a. Weight distribution

b. Guidance and control methods

c. Specific thrust

d. Reusability

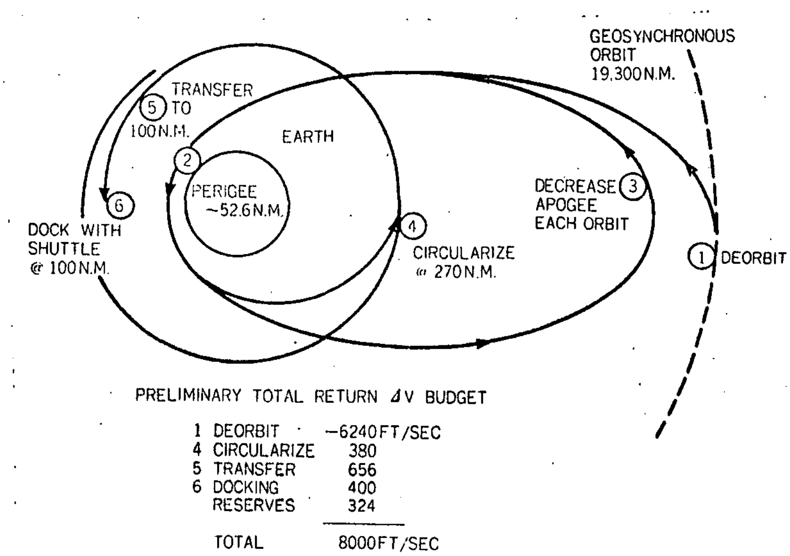
e. Long-term stay in space

f. Satellite recovery technique

g. Special mission techniques

h. Interfaces with shuttle payloads as well as control networks.

As an example, the current techniques being considered as a method of returning from a geosynchronous orbit to a shuttle is shown in Figure 34.



(Source: NASA)

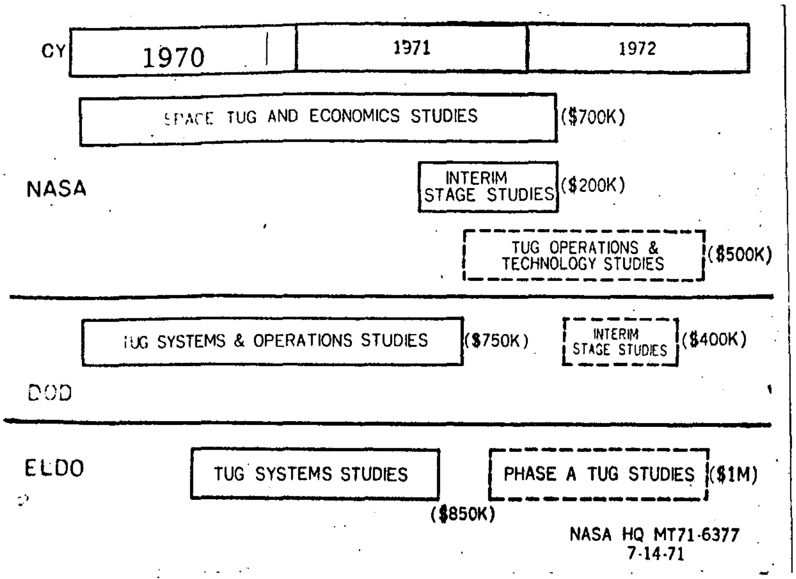
Figure 34.

(4) Status of Development and International Cooperation /43

Being different from a space shuttle, the space tug is being studied more or less independently by NASA, DOD and ELDO.

The developmental status and costs are given in Figure 35. It may be said that development is in the pre-Phase A stage.

ELDO is charged with items for the geosynchronous orbit and two groups of consortiums, HSD and MBB, are carrying out the studies. (Tables 15 and 16).



(Source: NASA)

Figure 35. Status of Space Tug Development.

TABLE 15. EUROPEAN INDUSTRIAL CONSORTIUM FOR A SPACE TUG.

Group Hawker Siddeley Dynamics		**Group Messerschmitt-Bölkow-Blohm**	
AIR LIQUIDE	France	British Aircraft Corporation	England
Bell Telephone	Belgium	CASA	Spain
Contraves	Switzerland	Compagnie Industrielle Radio-électrique (C.I.R)	Switzerland
Dornier Systems	Germany	ETCA	Belgium
ERNO Raumfahrttechnik	Germany	Eidgenössisches Flugzeugwerk	Switzerland
FIAT	Italy	AIR LIQUIDE	France
FOKKER	Holland	MARCONI	England
MATRA	France	SELENIA	Italy
MONTEDEL	Italy	SNTAS	France

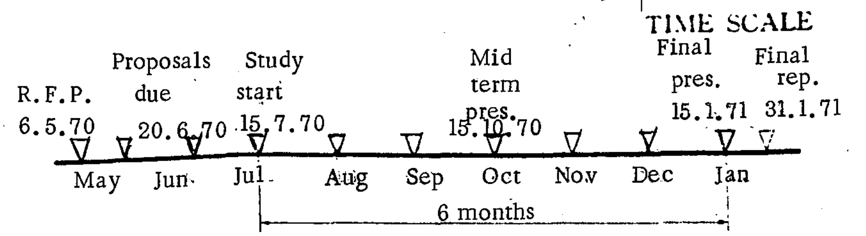
Group CRYOROCKET	
Messerschmitt-Bölkow-Blohm	Germany
Société Européenne de Propulsion	France

(Source: ELDO)

Figure 36 and Table 17 show the sketch of the lunar-landing tug and the development plans. Tables 18 and 19 summarize the configurations suggested by various companies. In addition, the concepts of the U.S.A. and Europe regarding a space tug are also given in Figures 37 and 38.

TABLE 16.

EUROPEAN TUG Pre Phase A Study



HSD-Team	MBB-Team	Engine-Team CRYOROCKET
L'AIR LIQUIDE	L'AIR LIQUIDE	MBB
BELL TELEPHONE	BAC	SEP
CONTRAVES	CASA	
DORNIER SYSTEM	CIR EFE	
ERNO	ELLIOTT	
FIAT	ETCA	
FOKKER/VFW	SELENIA	
MATRA	SNIAS	
MONTEDEL	VAN DER HEEM	

TABLE 17.

MARSHALL SPACE FLIGHT CENTER PROGRAM DEVELOPMENT	FY-73 PLANNING ACTIVITY	NAME: PD-SA-A-5 DATE: February 11, 1971

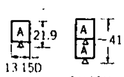
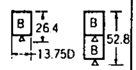
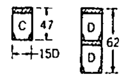
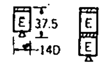
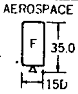
SYSTEMS CHRONOLOGY

SPACE TUG COMPONENTS	SP.SH.	SS	EXP.MOD.	RNS	SB
1. Propulsion Module (PM)	X------	------	------	------	------
2. Crew Module (CM)		X------	------	------	------
3. Cargo Module (CaM)		X------	------	------	------
4. Astrionics (A)	X------	------	------	------	------
5. Secondary Propulsion Element Tankage Kit (PM/SPE-T)		X------	------	------	------
6. Manipulator Arms (MA)			X------	------	------
7. Shielding (S)				X------	------
8. Landing Legs (LL)				X------	------
9. Environmental Control System (ECS)		X------	------	------	------
10. Other Kits	------	------	As Required	------	------

(Source: NASA)

TABLE 18.

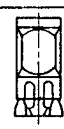
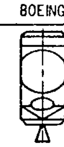
REUSABLE CONFIGURATIONS FOR GEO-SYNCH

VERSION	HSD		MBB		NAR		BOEING		AEROSPACE
	 21.9; 13.15D	41	 26.4; 13.75D	52.8	 47; 15D	62	 37.5; 14D		 35.0; 15D
	BASE STAGE	TANDEM REUSABLE	SINGLE STAGE REUSABLE	TANDEM REUSABLE	SINGLE STAGE REUSABLE	TANDEM REUSABLE	BASESTAGE	TANDEM REUSABLE	SINGLE STAGE REUSABLE
LAUNCH WT. (NO P/L)	21100#	42240#	38200#	•	89000#	101,000	47800#	95300	69,000
PROP (USABLE)	17500#	17500 EA ST	33000#	•	78000#	41,000 EA ST	39800 •	39800 EA ST	61,000
DRY WT.	3360#	3360 EA ST	3780#		11075	9065 EA ST	8000#	8000 1st 8140 2nd	6,380
λ	.826		.866		873	.810	832		.884
ENGINE THRUST	(1) 11,000#	(1) 11,000 EA ST	(1) 11,000		(4) 9000	(4) EA	(1) 23300#	(1) 23300 EA ST	23,800
ISP	450 SEC		460 SEC		463 SEC	463 SEC	460 SEC	460 SEC	460 SEC
DELIVERED P/L	Δ	4630# •	4630	16000#	10,000	10,000	Δ	(1) 10,000	11,000
RETRIEVABLE P/L	Δ	1560#	1890#	7925#	3900	3900	Δ	(2) 10,000	
ROUNDTRIP P/L	Δ	1170#	1340#	5640#			Δ	(3) 10,000	
LATEST APPROX. VALUES	400#	2200#	3300#	4700#					
	Δ NOT DEFINED • Delta Payload + 400 lbs for Isp - 460		• VARIES DEPENDING ON MISSION.				 (1) (2) (3) Stage conf. for noted P/LS		

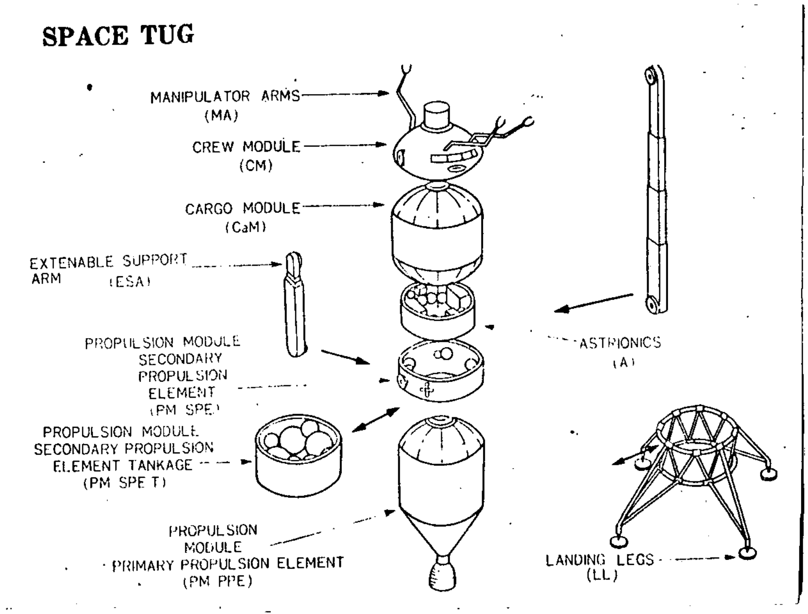
(Source: NASA)

TABLE 19.

CONFIGURATION COMPARISON

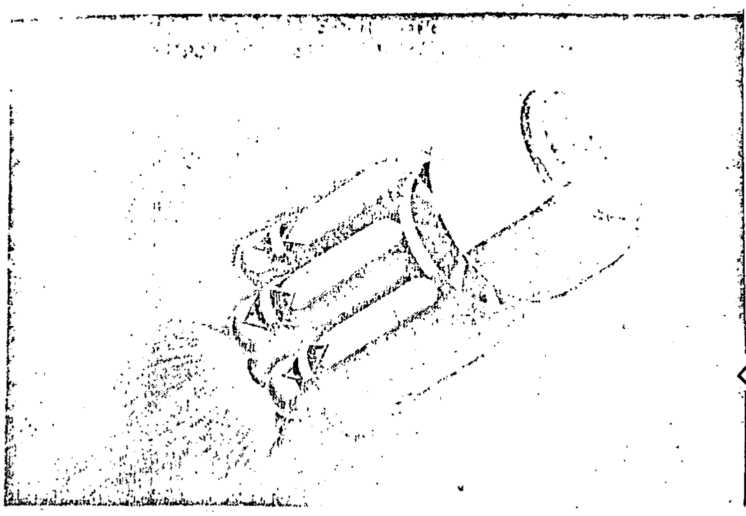
CONTRACTOR	HSD	MBB	NAR	BOEING	AEROSPACE
CONFIGURATION	 SPACE FRAMEWORK	 SPACE FRAMEWORK	 SKIN STRINGER	 SKIN STRINGER	 SPACE FRAMEWORK
TANKAGE ARRANGEMENT	1 LH_2 Tank 4 LO_2 Tanks	1 LH_2 Tank 4 LO_2 Tanks	1 LH_2 Tank 4 LO_2 Tanks	1 LH_2 Tank 1 LO_2 Tank	1 LH_2 Tank 1 LO_2 Tank
TANKAGE MATERIAL	Alum. (2021)	Alum. (2021)	Alum. (2219)	Alum. (2219)	Alum. (2021)
TANKAGE INSULATION	Closed cell Foam sub strate & H.P.I.	Closed cell Foam sub-strate & H.P.I.	H.P.I.	H.P.I.	H.P.I.
METEOROID PROTECTION	Honeycomb Panels-Nonstructural	H.P.I. Outer Jacket used as bumper	H.P.I. Outer Jacket used as bumper	Honeycomb Panel Alum faces with Hexcel core	Double walled panel Alum faces with open cell foam filler
DOCKING	Menasco type system	Menasco type system	Apollo probe and drogue type	Docking adapter kit	Aft mounted docking collar

(Source: NASA)



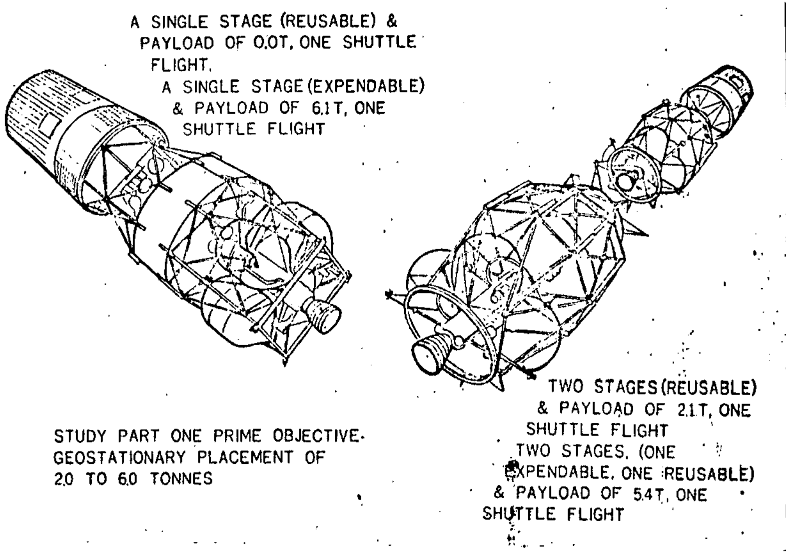
(Source: NASA)

Figure 36.



(Source: NASA)

Figure 37.



(Source: NASA)

Figure 38.

5. Skylab /48

(1) Outline

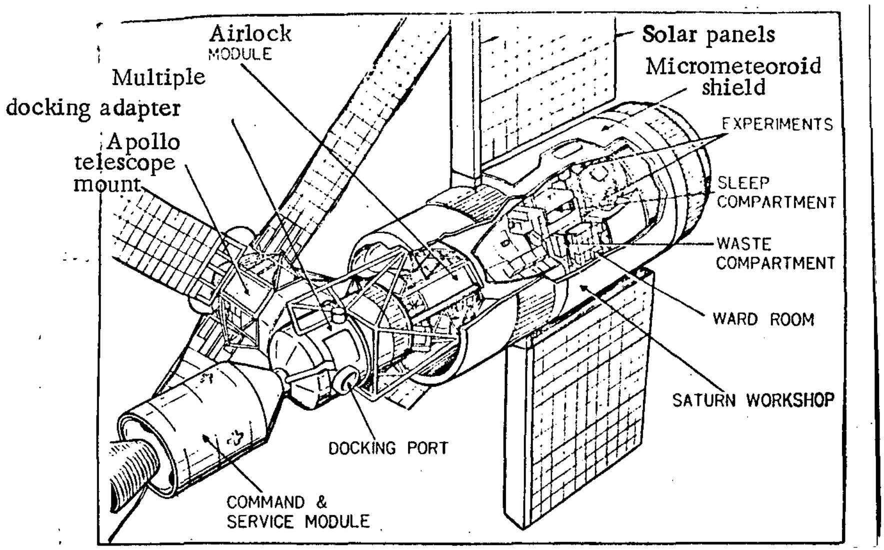
The Skylab program is the first manned flight program in the post-Apollo period. The purposes are collection of various data and carrying out some observations and scientific experiments required in the development of the space station which will be the ultimate space research base in the future.

The configuration of a Skylab shows that it consists of an orbital workshop (OWS), airlock module (AM), Apollo telescope mount (ATM), fixed airlock shroud (FAS) and multiple docking adapter (MDA) as seen in Figure 39(A) and (B). It is launched by use of a Saturn V type rocket to an orbit whose altitude is approximately 235 NM (430 km) and angle of inclination is 50°.

On the other hand, three crew members will be going to and from the Skylab by means of the command and service module (CSM) of an Apollo spacecraft which will be launched by means of a Saturn IB.

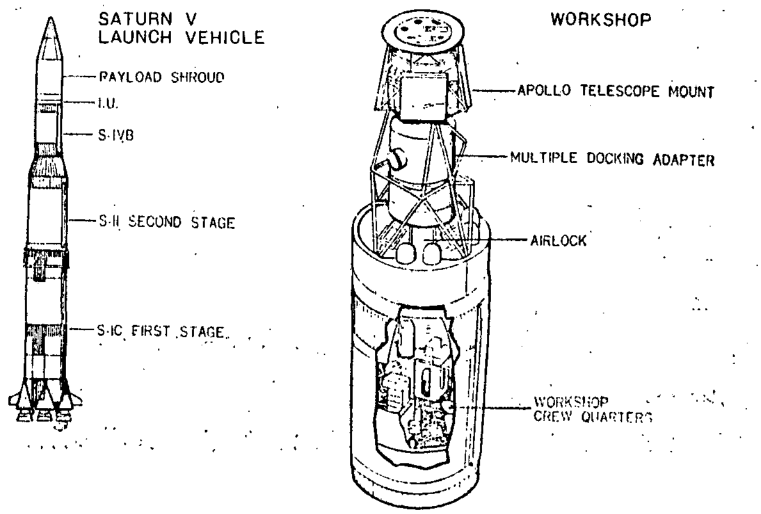
The OWS, which is a modified form of the third stage of the Saturn V (SIVB), has a diameter of 5 m and an internal capacity of 10,000 ft^3. This is divided into two stages; one of which is used for a physiological laboratory, a kitchen, a bathroom and a sleeping compartment, while the other is used for various scientific laboratories. The solar battery on the outside has a capacity of 16 kW.

(A)



(Source: NASA)

(B)



(Source: NASA)

Figure 39.

The AM is a cylindrical tunnel-type airlock with a diameter of 5.5 ft (approximately 1.7 m) connecting the OWS and MDA, through which the crew members can pass. It can be shielded against the pressure drop when it is necessary to go out into deep space. The digital command system is in this module and carries out functions such as real-time command of the OWS, data pressing and communications. There are also eight Ni-Cd batteries which will be charged by the solar battery attached to the OWS and will supply 3.83 kW of electric power in each period. The crew members will also be using this AM to enter and leave during the film changes of the Apollo telescope mount (four times in twenty-eight days).

The ATM is attached to the MDA and is used for solar observations. It is /50
expected to obtain various solar data on the Sun as an energy source, which cannot be obtained on Earth.

The experimental items of Skylab may be generally classified as follows:

a. Workshop habitability: Information gathering and evaluation of the habitability and environmental conditions which are useful for development of a space station in the future.

b. Medical: Research on the nutrition and functions of bone and muscle, function of coronary blood vessels, blood study, immunity study, neurological and physiological function, pulmonary function and metabolism by carrying out medical experiments for a long period of time in orbit.

c. Solar Astronomy: Solar observation by use of the ATM.

d. Astronaut Manuevering: Evaluation of the working and moving abilities of astronauts both inside and outside the Skylab.

e. Bioscience: Experimentation on human cells, plants, small animals, and insects under zero-gravity conditions.

f. Earth Resources: Collection of data which are important for future development of various sensors and photographic techniques. For example, obtaining information on a particular area by means of a multispectral photograph. Experiments including a ten-channel multispectral scanner, filter wheel spectrometer and active/passive microwave radiometer.

g. External contamination measurements: Investigation of the effects of wastes from the expendables around the Skylab and the ignition of propulsion systems as well as the distribution of micrometeorites.

h. Stellar Galactic Astronomy: Specific-amount-spectrophotography and x-ray observation of low-energy galaxies.

i. Materials Technology: Research on the properties of metals and other materials under zero-gravity conditions.

(2) Status of Development /51

The Skylab program was officially approved in August 1966 and most of the research topics have been determined. The contracts were awarded in October 1966. The work distribution within NASA is as follows:

Headquarters (overall), Marshall Spaceflight Center (MSFC) (Skylab), Manned Spacecraft Center (MSC) (Saturn V), and Cape Kennedy (launch). The work distribution among the manufacturers is listed in Table 20. Also, both MSFC and MSC are in charge of crew training and machinery and instrument testing.

TABLE 20. BUILDERS FOR SKYLAB.

Boeing	1st Stage of Saturn V
Chrysler	Saturn IB
Martin	MDA, ATM
MDC	AM, OWS, STVB of Saturn IB
NAR	CSM

Note: 1) MDC has a $400 million contract for AM and OWS. Its contents are two flight models, three training models and two partial test models.

s) Total cost of Skylab-A is approximately $2.2 billion.

For Skylab-A, hardware for a back-up model (excluding the research instruments) is also being constructed beside the flight model. If successful the first time, the back-up model will be launched in 1975 as Skylab-B after new research topics are assigned. This Skylab-B program is not yet officially approved but there is a possibility of participating in this program.

(3) Missions

The launch of Skylab-A is scheduled in May 1973 with the following missions.

Mission 1: Launch the Skylab with the Saturn V. /52

Mission 2: Launch three astronauts by using the Saturn I B type. These crew members will ride in CSM, dock with the Skylab, carry out experiments for twenty-eight days and return to the Earth in a CSM like an Apollo spacecraft.

Mission 3: The same as Mission 2, except that the period is fifty-six days. (Start the mission sixty-one days after the completion of mission 2.)

Mission 4: The same as Mission 3. (Start the mission thirty-four days after the completion of Mission 3.)

6. Viking Program /53

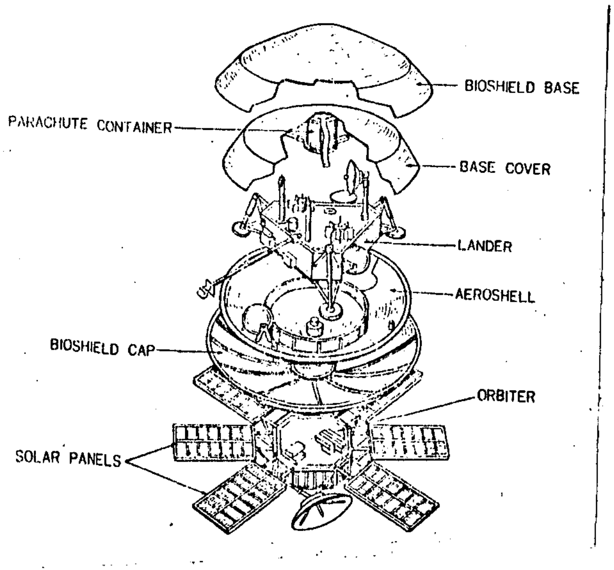
(1) Outline

The Viking Program is a Mars exploration program which succeeds the Mariner IV launched in 1964, the V of 1969 and the VII of this year. The launch is scheduled for either August or September, 1975 and landing is expected to be July or August of 1976. The exploration of the soil of Mars will be carried out until March 1977.

The structure of the Viking spacecraft may be divided into two parts, the Lander part which will land on Mars and the Orbiter part which will be orbiting Mars as an artificial satellite (Figure 40).

It measures 14 ft (approximately 4.3 m) in diameter and 16 ft (approximately 7,955 lbs (3.6 tons) which consists of 2,365 lbs (1.1 tons) for the Lander, 275 lbs (0.1 ton) for its fuel, 5,069 lbs (2.3 tons) for the Orbiter and 3,098 lbs (1.4 tons) for its fuel.

The Viking is to be launched by the Titan II Centaur. The mission sequence until the landing on Mars is sketched in Figure 41. /54



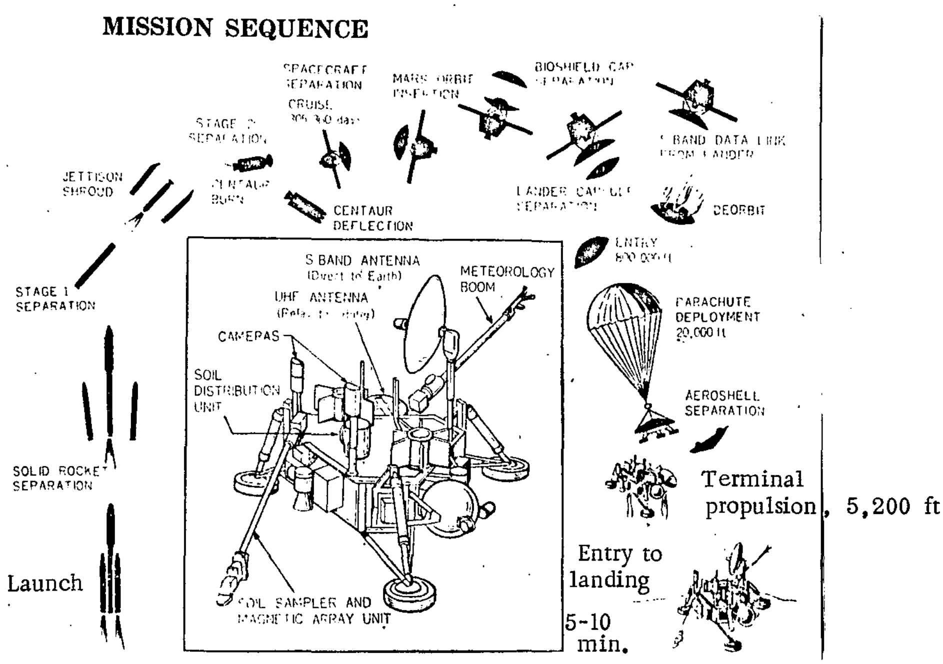
(Source: NASA)

Figure 40.

(2) Observation Items

a. Orbiter and Observation Items

After the Orbiter becomes a satellite of Mars, it will send the Lander to land on a fixed site on Mars. Then the Orbiter will monitor the landing position and relay communications. It will also survey the atmosphere and the surface of Mars. Accordingly, it is designed to gather and transmit information to Earth before separating from the Lander in order to select and confirm a landing site.



(Source: NASA)

Figure 41. Mission Sequence.

After the Lander has separated, the Orbiter acts as a relay station for data sent by the Lander to the Earth and also makes measurements of the atmosphere of Mars (Table 21).

TABLE 21. MAJOR SCIENTIFIC INSTRUMENTS TO BE CARRIED IN THE ORBITER.

SCIENCE INVESTIGATIONS	INSTRUMENTS
Imaging	Television cameras
Water Vapor Mapping	Infrared spectrometer
Thermal Mapping	Infrared radiometer
Radio Science	Radio Subsystem

(Source: NASA)

b. Lander and Observation Items /55

The greatest concern in Mars exploration is to find out whether life exists or not. Because of this, the Lander has to undergo heat sterlization, contained in a capsule, before launch so that the probability of any living /56
things from the Earth remaining becomes less than one in a million.

The major scientific observation items and the instruments of the Lander are listed in Table 22.

c. Data

It is necessary to improve the output of the spacecraft, the efficiency of the antenna and the capacity of the receiving station on Earth in order to transmit the voluminous information to the Earth, which is 3.7×10^8 km distant. For this purpose, the construction of a receiving antenna with a diameter of 120 m is under consideration.

2

TABLE 22. MAJOR SCIENTIFIC INSTRUMENTS ON THE LANDER.

SCIENCE INVESTIGATIONS	INSTRUMENTS
Imaging	2 cameras, stereo and color
Biology	4 metabolism and growth experiments
Molecular Analysis	Gas chromatograph/mass spectrometer
Atmospheric Composition	Mass spectrometer and retarding potential analyzer
Atmospheric Structure	Pressure and temperature sensors and accelerometers
Meteorology	Pressure, temperature, wind and humidity sensors
Seismic Background and Events	3-axis seismometer
Magnetic Properties	Magnets
Physical Properties	Cameras, sampler, engineering sensors

(Source: NASA)

(3) Development Schedule and Cost

The major milestones in the Viking Program are as follows:

October 1969	-	Start of the project
December 1969	-	Selection of scientific observation items
October 1970	-	Mission commitment
January 1971	-	Examination of mission and system requirements
February 1971	-	Initiation of examination of the preliminary design of the Lander
September 1971	-	Completion of examination of the preliminary design of the Lander
October 1971	-	Completion of examination of the preliminary design of the Orbiter
January 1971	-	Completion of examination of the preliminary design of the components of the Lander
May 1972	-	Completion of examination of the preliminary design of the subsystem of the Orbiter
February 1972	-	Completion of the critical design of the Orbiter
March 1973	-	Completion of the critical design of the Lander
January 1974	-	Titan/Centaur test launch

April 1974	-	Assembly of the Lander and the Orbiter (JPL)
August 1974	-	QT (Quality Test) completion
March 1975	-	Assembly of S/C (spacecraft) and Titan III/Centaur (Cape Kennedy)
August or September 1975	-	Launch

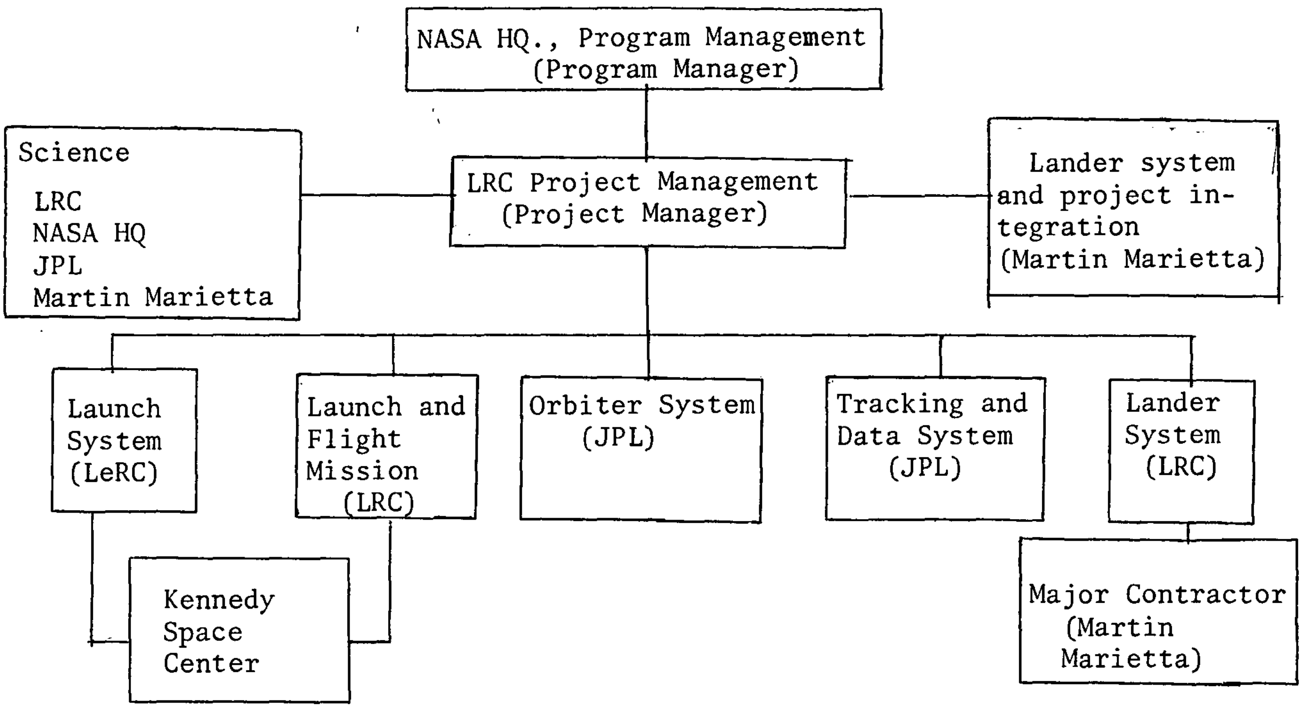
/57

The cost of this program, excluding the launch cost, is approximately $250 million.

(4) Development System

The project team for the Viking program is at NASA Headquarters. The Lander is the responsibility of the Langley Research Center (LRC) while the Orbiter and the data tracking are under the Jet Propulstion Laboratory (JPL) (Table 23).

TABLE 23.



(Source: NASA)

/58

7. TOPS Project (Grand Tour Project)

(1) Outline

The TOPS Project (Thermo-Electric Outer-Planet Spacecraft Project) is a program to carry out observation of several planets by means of one spacecraft during the 1970s and 1980s by taking advantage of the opportunity when the positions of the planets become extremely good for observations, which occurs every 175 years. There are several proposals at present for the flight paths. However, each of them includes a fly-by of Jupiter (J) or Saturn (S) or both and to carry out the flight using their gravities. The orbit and launch time to fly-by one or two planets in the group composed of Uranus (U), Neptune (N) and Pluto (P) are already computed. Examples are shown in Figure 42 A and B. For the launch, a Titan III D/Centaur/Burner II rocket is being considered.

At present, the design is not finalized but the results of study as of today are shown in Figure 43. As seen in the figures, it has a weight of 1,500 ~ 2,000 lbs and carries many conventional observation instruments. However, it should be noted that it also contains some new technical developments such as use of RTGs (Radioisotope Thermo-Electric Generators) for its power source.

(A)

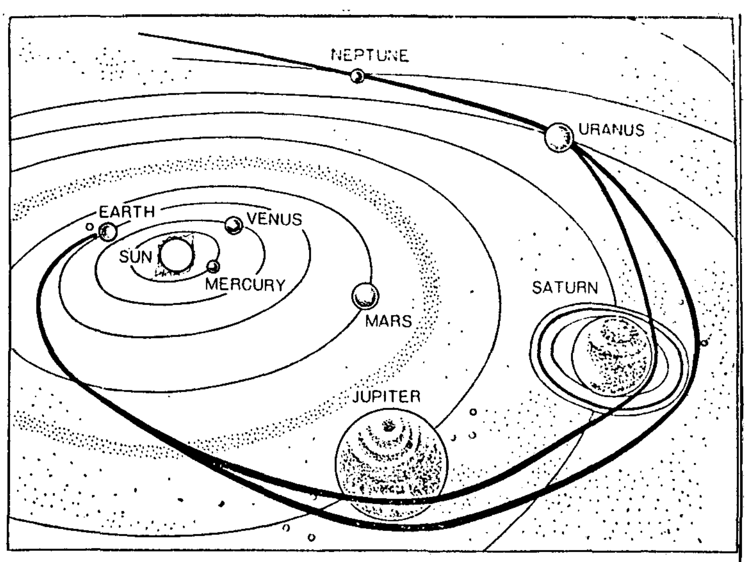
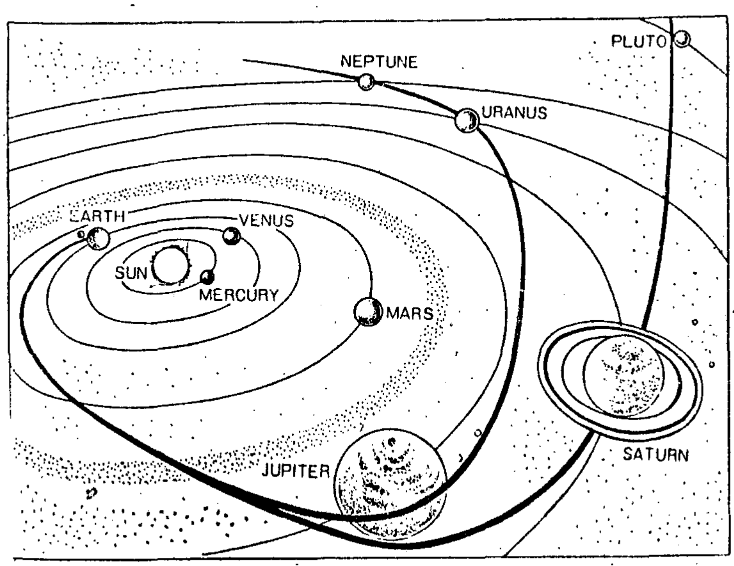


Figure 42 A. Orbits for Grand Tour Project.

(B)



(Source: Astronautics and Aeronautics September 1970 issue)

Figure 42 B.

As Table 24 indicates, it would take approximately ten years to reach Neptune or Pluto and thus the problem of reliability should be studied sufficiently. Also, the distance from the Earth becomes extremely great. Therefore, many considerations are being made regarding data transmission. Although the final flight path is not decided, the JPL project is well under way and ten research centers among the six European countries are participating in the project.

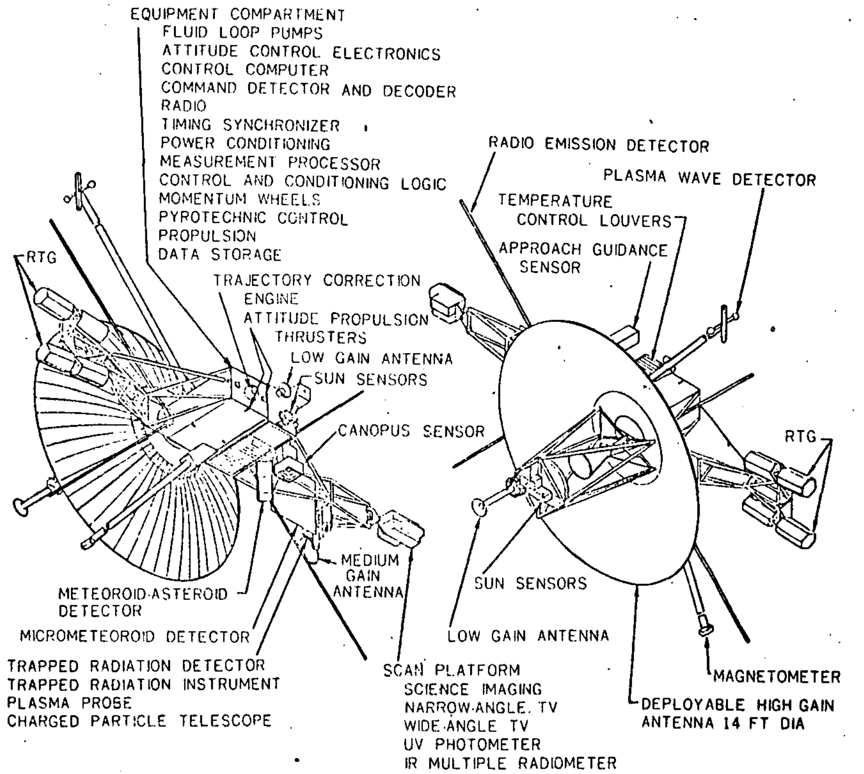
The cost of this project is approximately $750 million (four spacecraft).

8. <u>Other Projects</u> /62

Other noteworthy projects are HEAO and the LST projects.

(1) HEAO

The purpose of the HEAO (High Energy Astronomical Observatory) project is to carry out a large-scale observation of x-ray, γ-ray and other high-energy cosmic rays by launching an observatory into orbit.



TOPS SPACECRAFT IN MOST RECENT CONFIGURATION

Total spacecraft launch weight: 1445 lb.
Total spacecraft power required: 249-439 w. depending on mission phase.
Structure. Central bus, deployable antenna; deployable science and RTG booms.
Radio Redundant receivers, five S-band transmitters; two-X band transmitters.
Antennas. Two low-gain, one steerable medium-gain; one deployable high-gain.
Data rates Variable from 131,072 to 8 bps.
Command and control. Onboard decision-making with backup ground control; synchronous spacecraft timing.
Power source: Radioisotope thermoelectric generators (RTGs).
Measurement processing; Programmable sampling and data compression; 512 analog and digital engineering sensors; separate channel for multiplexed science data.
Attitude control: Stabilized in three axes by momentum wheels and hydrazine thrusters.
Propulsion: Hydrazine trajectory-correction engine.
Thermal control: Passive shields, fluid loop, and resistance heaters.
Navigation: Earthbased ranging and doppler tracking; onboard optical measurements for approach guidance.
Data storage: Mass storage (2×10^9 bits) and serial buffer storage (8×10^6 bits)

(Source: Astronautics and Aeronautics September 1970 issue)

Figure 43. Configuration of TOPS (Spacecraft).

TABLE 24.

TOPS TRAJECTORY DATA

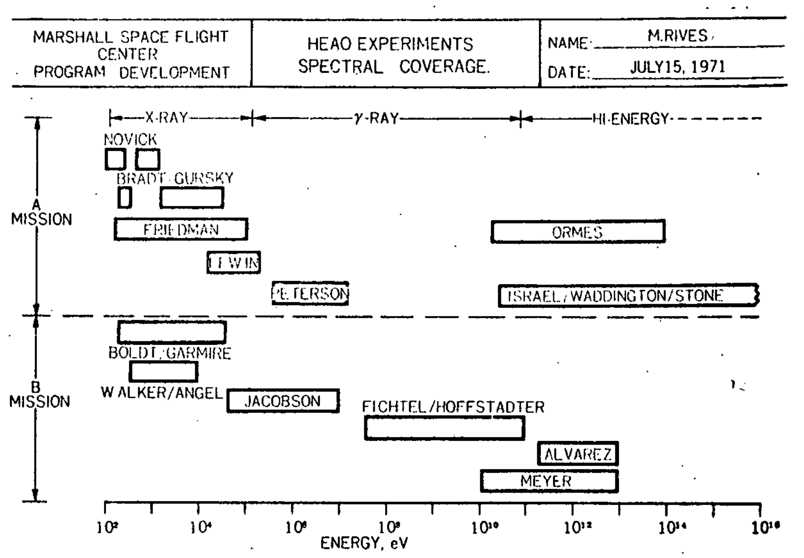
Mission	Launch date	Launch energy* km^2/sec^2	Launch period, days	Flight time, years	Planet-encounter dates	Altitude at closest approach 10^3 km	Hyperbolic approach velocity, km/sec
1977 Grand Tour inner-ring trajectory	9/4/77	120	18	9.2	Jupiter: Jan 29, 1979	217.9 (3.0 radii)	11.97
					Saturn: Sept 3, 1980	6.4 (0.1 radius)	16.56
					Uranus: Feb 1, 1984	21.3 (0.9 radius)	21.07
					Neptune: Nov 8, 1986		23.57
1977 J-S-P	9/4/77	120	21	8.5	Jupiter: Feb 6, 1979	230 (3.2 radii)	11.8
					Saturn: Sept 12, 1980	452 (7.5 radii)	16.3
					Pluto: Mar 9, 1986		18.5
1979 J-U-N	11/6/79	120	21	9.1	Jupiter: Apr 30, 1981	413 (5.8 radii)	12.2
					Uranus: Jul 28, 1985	25 (1.1 sadii)	16.3
					Neptune: Nov 28, 1988		17.3

* Vis viva energy, or injection energy of the escape hyperbola, of twice the total energy per unit mass, commonly designated as C_3.

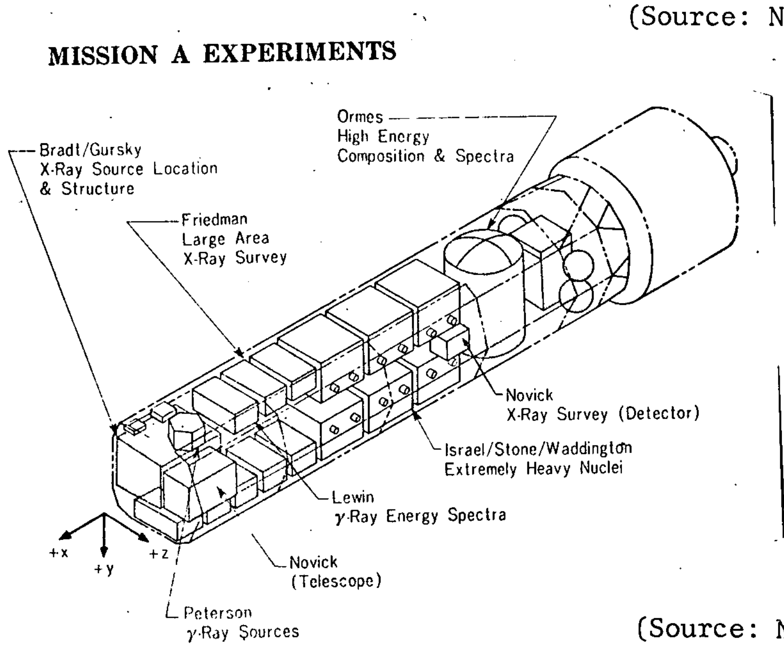
(Source: Astronautics and Aeronautics September 1970 issue)

Currently, the HEAO-A and HEAO-B projects are under way. Their research contents and principal investigators are shown in Tables 25 and 26. The configurations of the observatory are given in Figures 44 and 45. The research teams for this project include many scientists from Europe.

TABLE 25.



(Source: NASA)



(Source: NASA)

Figure 44. Mission A Experiments.

TABLE 26. HEAO EXPERIMENTS.

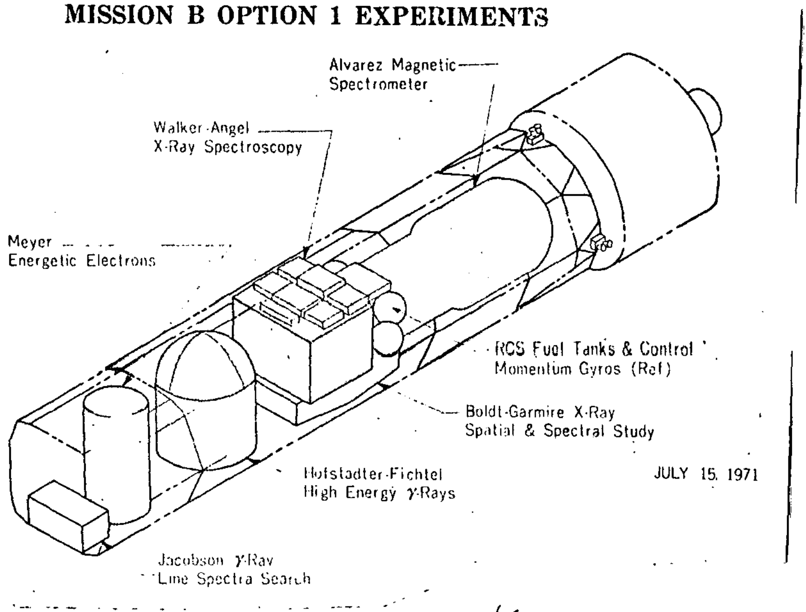
EXPERIMENT NO.	TITLE	PRINCIPAL INVESTIGATOR
Mission B AXR-1	Focusing X-Ray Experiment	Novick
AXR-2	Combined Modulation Collimator Experiment	Bradt/Gursky
AXR-3	LAXRAY	Friedman
AGR-4	MeV Range Gamma-Ray Telescope	Peterson
AGR-5	HEXRAY	Lewin
ACR-6	Hi Energy Cosmic Ray Experiment	Ormes
ACR-7	Heavy Nuclei Experiment	ISW
Mission A BXR-1	Diffuse X-Ray Measurement	Boldt/Garmire
BXR-2	Bragg Crystal X-Ray Spectrometer	Walker/Angel
BGR-3	High Spectral Resolution Gamma-Ray Spectro-meter	Jacobson
BGR-4	High Energy Gamma-Ray Spark Chamber Teleseope	Fichtel/ Hofstadter
BCR-5	Superconducting Magnetic Spectrometer	Alvarez
BCR-01	High Energy Electron Experiment	Meyers
BCR-02	Isotopic Composition of Primary Cosmic Ray Experiment	Koch/Peters

(Source: F. Peter Simmons/Grumman)

HEAO-A and B are expected to be launched in 1974 by Titan III rockets into a circular orbit with an altitude of 200 N.M. (370 km) and angle of inclination of 28.5°. Following these, launches of HEAO-C in 1977 and HEAO-D in 1978 are also planned. /63

(2) LST /65

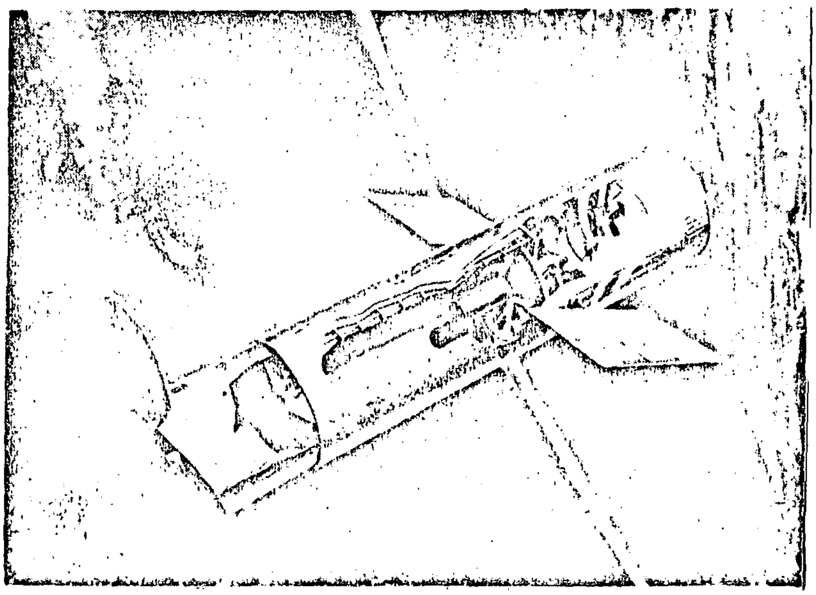
The LST (Large Space Telescope) is a project to launch a large telescope into orbit for astronomical observations by expanding the OAO (Orbiting Astronomical Observatory) project.



(Source: NASA)

Figure 45. Mission B Experiments.

The telescope has an aperture of 120 inches (approximately 3 m) and can observe up to *29th* magnitude stars (Figure 46, Table 27).



(Source: NASA)

Figure 46.

TABLE 27. OBSERVATORY PERFORMANCE COMPARISON.

Characteristics	Ground Based	OAO-2	OAO-B	OAO-C	OAO/LST
Aperture	200 inch	1-16 inch 6- 8 inch	38 inch	32 inch	120 inch
Wavelength	3, 000Å- 10, 000Å	1, 100Å- 4, 000Å	1, 100Å- 4, 000Å	950Å- 3, 300Å Plus X-Ray	1, 000Å- 300, 000Å
Guidance Stability	±0. 5 Arc Sec	±3 Arc Sec	±0. 25 Arc Sec	±0. 03 Arc Sec	±0. 004 Arc Sec
Limiting Star Magnitude	23	10	14	7	29
Instrumentation	IR Visible	Ultra Violet	Ultra Violet	Far Ultra Violet X-ray	IR Visible Ultra Violet
Size	—	8 Ft dia 10 Ft Lg	8 Ft Dia 10 Ft Lg	8 Ft Dia 10 Ft Lg	13 Ft Dia 45 Ft Lg
Weight	—	4, 200 Lb	4, 700 Lb	4, 800 Lb	22, 000 Lb

(Source: F. Peter Simmons/Grumman)

PART 2. ATTITUDE OF EACH NATION ON THE POST-APOLLO PROGRAM

1. The United States of America

(1) Outlook

For the last ten years, the major purpose of the space program in the U.S.A. has been to send human beings to the Moon. However, NASA, which is directing the post-Apollo program, is planning full-scale space activities for the coming ten years by utilizing the achievements and technology obtained thus far, which will include practical aspects such as communications, atmospheric phenomena, space travel, monitoring of national disasters and surveying resources as well as scientific aspects such as astronomy and exploration of the planets and space. /67

In carrying out these projects, NASA is particularly interested in the promotion of international cooperation. At the same time, it is giving economic considerations primary attention and therefore devoting a large effort to the development of low-cost space transportation systems such as the space shuttle and space tug.

(2) Outlook for Program

It seems likely that more details regarding the total post-Apollo program and its schedule may come to light by the end of this year (1971).

As one of the external conditions which may accelerate the program, the behavior of the Soviet Union may be considered. However, no such specific conditions stimulating the program have been found at present. It seems that the present course is to arouse public sentiment by stressing the significance of the program and thus obtaining public support.

In the explanation of the significance of the program, the following points can be emphasized in particular.

(a) Now is the time when space development is useful in many fields, not only for a nation but also for the promotion of the welfare of all mankind.

b It is necessary to continue space exploration even more actively in /68
order to increase human knowledge and to further expand the scientific achievements obtained thus far from the development of space.

c It is necessary to develop techniques to achieve space programs more economically.

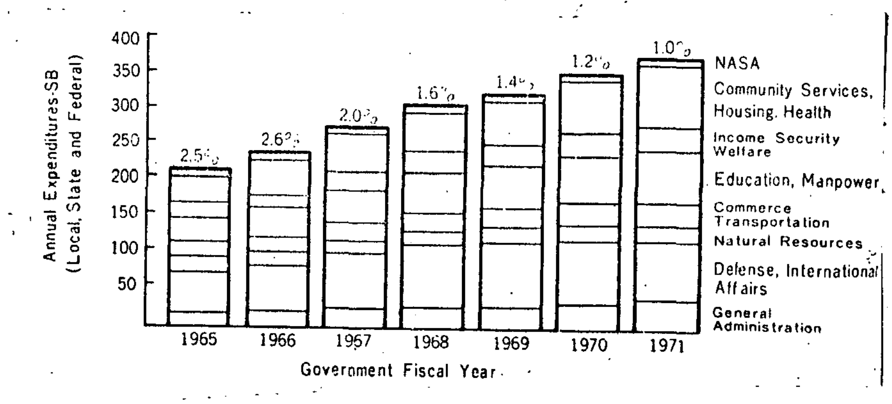
d There is much significance in the fact that the U.S.A. is in the lead in these matters.

The annual NASA budget was at its peak in the middle 1960s, with approximately $6 billion. It has shrunk since then and now stands at $3 billion. Looking at the ratio of this to the total national expenditure, it has dropped from 2.5% to 1% (Table 28 and Figure 47).

TABLE 28. TREND OF SPACE PROGRAM BUDGET IN THE U.S.A. (UNIT: MILLION DOLLARS).

Year	1961	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72
Amt. allocated	744	1,257	2,552	4,170	5,091	5,933	5,423	4,721	4,247	3,749	3,368	3,151

(Source: Appendix of the U.S. 1972 budget)



(Source: McDonnell Douglas)

Figure 47. The Ratio of NASA Budget to Annual Expenditure.

According to the authorities, however, it is estimated that the budget will be raised to some $4 billion in the mid-1970s when space shuttle development reaches full scale. This estimation has been brightened by the fact that the Joint Committee of the U. S. Congress on Space passed the budget by adding $80 million more than the Government requested. /69

The public opinion on the program may not all be favorable. However, if we consider that the action of the Congress is not contrary to public opinion, it may then be conjectured that there is no great opposition, as we saw in the budget increase described above.

The most difficult part is the reaction of the Government agencies, especially that of the financial authorities. NASA people think that the requested budget is more or less approved at present, which may indicate that the program is once again understood.

In the post-Apollo programs, the budget for a "manned program" has been cut considerably with the completion of the Apollo program. However, the "unmanned program" is expanding gradually and costs less from an economical viewpoint; it would not be affected by the budget cut and would continue its steady growth at the current rate.

(3) Effects

a. Effects on Technical Advancement

If we assume the viewpoint of the effects on technical advancement, it is generally felt that the post-Apollo program, which has more developmental elements, will have greater effect as compared with the Apollo program.

b. Effects on Industry

With the completion of Apollo-related tasks, the suspension of SST development as well as the absence of any noteworthy aircraft-related projects, the aerospace industry in the U.S.A. is suffering at present, to the point where most firms have to reduce their manpower tremendously (by 40 to 70%). Therefore, it is not at all difficult to imagine that the direction of the post-Apollo programs, especially the space shuttle, space tug and space station which form the heart of the program, will have an extremely important effect on the aerospace industry in the future. /70

(4) Attitude of Business

American businesses have a very positive attitude toward the post-Apollo program.

In regard to the space shuttle in particular, several companies are competing with one another in carrying out the Phase B studies. Since the company which will be responsible for the development will be selected in a year or so (the engine contracts were awarded on July 10, 1971), it seemed that each company was filled with unusual enthusiasm. The contracts currently in effect do not offer these companies any profit. On the contrary, most companies are spending approximately 1.5 times the amount received from NASA from their own funds. Once a company is appointed as the prime contractor, however, it will obtain work worth $3 to 4 billion. According to the business world, it is like an investment although there may be some risks involved.

2. Europe in General /71

(1) Outlook

The active consideration by Europe of the post-Apollo program started in October 1969 when Dr. Paine, the NASA Administrator, visited Europe. At that time, the European countries were formulating a space development program with ESC (European Space Conference) as its center. Since the post-Apollo program was very important, it was realized that the contents of the program should be understood and the relationship between it and the European program should be considered. Consequently, negotiations with NASA started at the beginning of 1970, through ESC.

(2) Fundamental Thoughts of Europe

The thoughts of Europe on the post-Apollo program may be summarized as follows:

a. Although there is some difference in degree, each nation has a favorable opinion.

b. They think that it is necessary to understand the contents of the program exactly before participation is decided on.

c. It is hoped that participation will involve gathering European countries together to work collectively. The arrangement for this purpose will be carried out by ESC.

d. The greatest problem is how to combine the post-Apollo program and the European program.

e. There are many unclear points in the post-Apollo program as of now. This may be due to several unclear situations with respect to expenses and timing, although the program designers in the U.S.A. have clear ideas.

f. Even though the post-Apollo program is well established technically, there may be many changes from the initial plan or it may be necessary to extend the time due to other situations. Anyhow, it is almost certain that the program will be accomplished in one way or another.

g. As long as the reasons as to why the attitude of Europe in the participation has not yet been decided are concerned, both Europe and the United States have their own problems and it is not possible to say exactly what the causes are. /72

h. The merits of participation are considered to be as follows:

(a) Contribution to the development of science and technology

(b) Importance of new technology

(c) Profits in the industrial sphere

(d) Extended effects on other industries

(e) Political effects

(f) Obtaining information.

i. The conditions for participation are being negotiated with the U.S.A.

It was shown previously that the amount pledged by the United States of America to Europe was hoped to be approximately 10% of the developmental cost for space shuttle and space tug.

This 10% is a large amount of money which is close to the total developmental cost of the Europa-III program which is being planned by Europe at present. If the U.S.A. offers the rockets (launch vehicles) which are desired by Europe under an adequate plan, it will be possible for Europe to participate in the program without much difficulty.

Accordingly, Europe has conveyed its desire for proper rockets to the U.S.A. but it has not yet received a reply.

j. It is not possible to forecast the exact date when the decision on participation will be finalized. According to one source, some answer may be obtained by the end of this year.

However, that may be, it should satisfy the following conditions

(a) Clear direction of allotment

(b) Clear indication that there is more to be gained by participation even if Europe has to stop its own rocket development.

k. They would very much welcome an exchange of information and ideas /73 with Japan.

(3) European Organizations on the post-Apollo Problem.

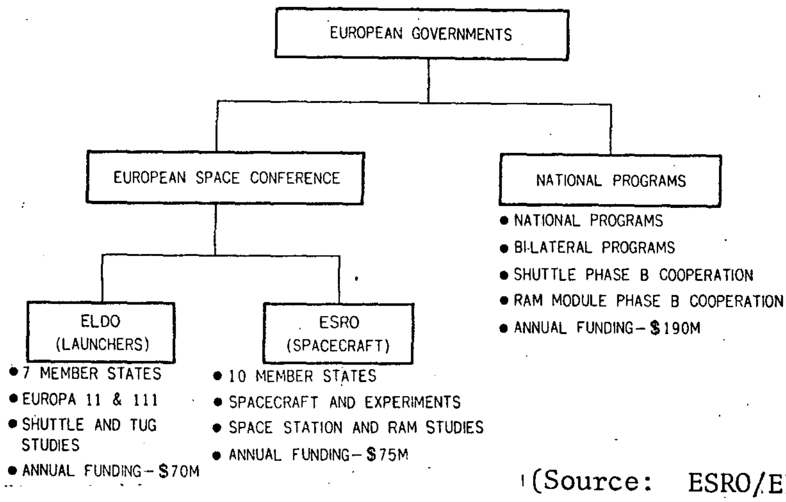
The international cooperation organizations of Europe concerned with space development are shown in Figures 48 and 49. The Ad-Hoc Committee in Figure 49 was formed to carry out negotiations with the U.S.A. on this problem. The liaison office of ESC is in Washington, D. C., where two officers are constantly posted.

(4) Budget

ELDO and ESRO are supposed to pay $6 million in relation to the post-Apollo program for two years beginning in 1970. Its contents are as follows:

Research on space tug (pre-Phase A) Technical research on space shuttle	$4 million
Space station, RAM (Research and Applications Module)	$2 million

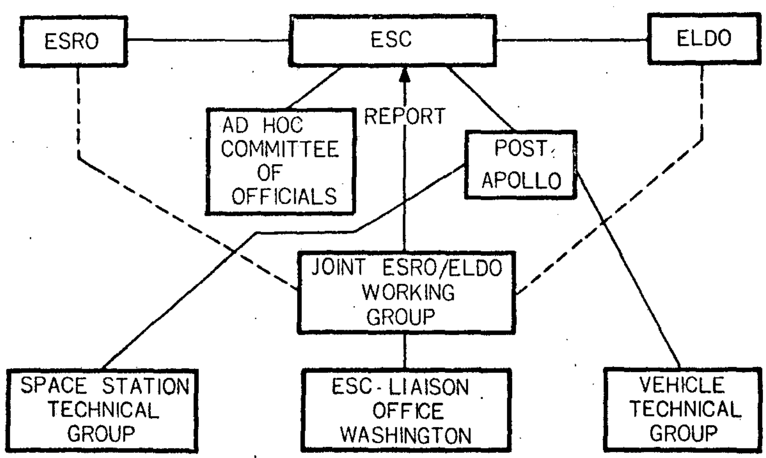
INTERNATIONAL COOPERATION-POST APOLLO EUROPEAN EFFORT-FY 1971



(Source: ESRO/ELDO)

Figure 48.

PRESENT STATUS OF EUROPEAN ORGANISATION FOR EXAMINING PARTICIPATION IN THE POST-APOLLO-PROGRAMME



(Source: ESRO/ELDO)

Figure 49.

(5) Present Status of Post-Apollo-Related Projects

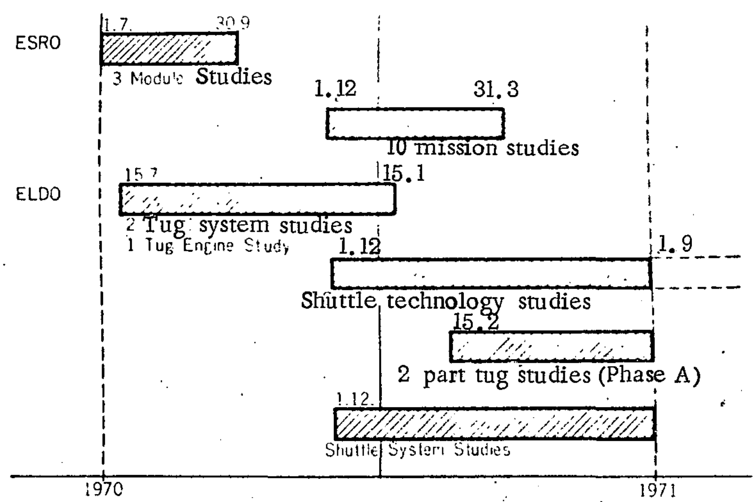
The schedules of ESRO and ELDO for various items are shown in Table 29.

a. Space Tug

As Table 30 shows, there are two groups which are working with space tugs. These tugs have two stages and their purpose is to place satellites in geostationary orbits as well as to recover these satellites.

Cooperation with the U.S.A. on this research is carried out by selecting one project manager from each side to perform the coordination, which is going smoothly. The results of the research will go to the U.S.A. but Europe will receive more information than that which it obtains from the U.S.A. /76

TABLE 29. SCHEDULE FOR EUROPE (ESRO/ELDO) ON THE POST-APOLLO-RELATED DEVELOPMENT.



(Source: ESRO/ELDO)

There is also a group called Cryorocket which is doing research on the engine used for attitude control (ACPS).

b. Space Shuttle

In regard to the space shuttle, each company is working in accordance with the aims listed in Table 31. This is achieved by receiving specifications from NASA.

TABLE 30.

EUROPEAN INDUSTRIAL SPACE TUG CONSORTIA

Group Hawker Siddeley Dynamics		**Group Messerschmitt-Bölkow-Blohm**	
Air Liquide	France	British Aircraft Corporation	England
Bell Telephone	Belgium	CASA	Spain
Contraves	Switzerland	Compagnie Industrielle Rádio-électrique (C.I.R.)	Switzerland
Dornier Systems	Germany	ETCA	Belgium
ERNO Raumfahrt-technik	Germany	Eidgenössisches Flugzeugwerk	Switzerland
FIAT	Italy	Air Liquide	France
Fokker	Holland	Marconi	England
MATRA	France	Se'enia	Italy
Montedel	Italy	SNIAS	France

Group CRYOROCKET

Messerschmitt-Bölkow-Blohm	Germany
Société Européenne de Propulsion	France

(Source: ELDO)

TABLE 31. RESEARCH AREAS FOR EUROPEAN COMPANIES.

1. FIBRE COMPOSITES	
U. K.	Hawker Siddeley Aviation Ltd. "Carbon fibre/Epoxy resin stringer/Skin panels"
U. K.	British Aircraft Corporation Ltd. "Reinforcement of metal structure by unidirectional carbon fibre"
Germany	M. A. N. "Reinforced metallic tanks"
Holland	Fokker/VFW "Mixed structure study"
2. THERMAL PROTECTION SYSTEM	
Italy	FIAT "Non-metallic thermal protection panels"
France	Avions Marcel Dassault "Metallic Thermal Protection Systems"
Belgium	University of Liege/SANCA "Thermal stresses : stability and flutter analysis of a TPS"

TABLE 31. (Continued)

3. THERMAL FACILITIES	
Switzerland	Sulzer Brothers Ltd. "Thermal fatigue plant"
FRANCE/GERMANY	CRYOROCKET (GIE MBB/SEP) "Study and Technological Work on some aspects of the US-Space Shuttle auxiliary propulsion system"
U. K.	ROLLS-ROYCE 1971 Limited "Work on Lox pump inducers"
ITALY	OTO-MELARA "Study on some aspects of the gas phase portion of the auxiliary propulsion system"
HOLLAND	T. N. O. "Advanced calibration methods for transducers"
1. DATA SYSTEMS	
Italy	Montedel "Vehicle Data Exchange System"
2. GUIDANCE, NAVIGATION AND CONTROL	
Italy	Selenia "Rendez-vous and Docking Radar System"

(Source: ELDO)

c. Space Station

The research on the space station is carried out mainly by ESRO.

Its purposes are:

(a) Research on modules

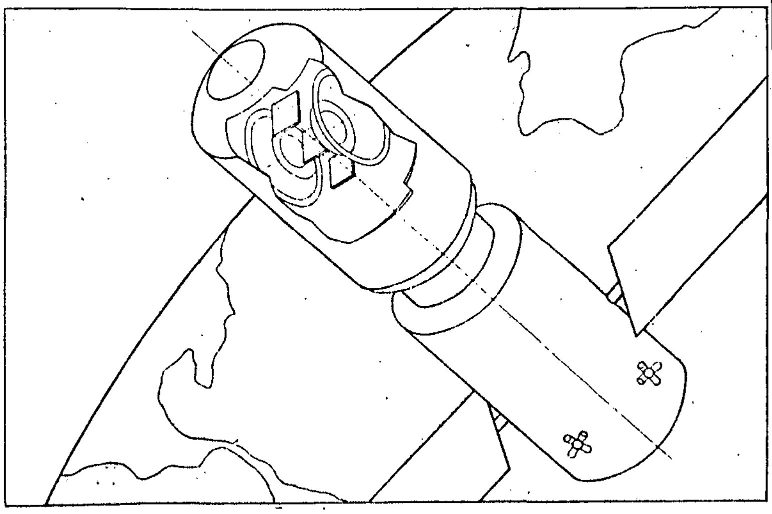
(b) Evaluation of the "manned program"

(c) Preparation for participation.

These modules include three types such as "astronomy," "biology," and "cosmic ray" (Figure 50). The "biology" module is an attached type while the /77 others are free-flying types. The fields of research and the contents of the budget (July 1970 to June 1971) of approximately $600,000 are as follows.

(a)	Cost survey of RAM	$180,000
(b)	Experimental Apparatus aboard RAM	
	Scientific field	$20,000
	Application field	$35,000
(c)	New field to be explored by the post-Apollo program	$45,000
(d)	Engineering	$15,000
(e)	General	$85,000
(f)	Analysis of post-Apollo system	$210,000

COSMICS RAY MODULE



(Source: ESRO)

Figure 50.

Summarizing the above, Europe has not determined the areas of its participation as yet but it is carrying out technical research actively and trying to grasp the contents and problems of the post-Apollo program through this research. /79

This is based on the consideration that this research will be useful when participation is decided on and that the investment will not be totally wasted even though there is some risk if it is decided not to participate, because this research can be applied.

/80

3. Status of Each European Country

(1) The United Kingdom

a. Outline

The basic attitude of the United Kingdom in regard to the space program is to proceed with the emphasis on the utilization of space. This is clear from the fact that the development of the satellite has great importance in space development plans and that the ratio of the budget at ESRO and INTELSAT has been increasing on the side of international cooperation. Also, unlike the U.S.A. and France, no unification of the administrative organizations of the space programs is carried out. This may also imply the policy which emphasizes application (Tables 32, 33).

TABLE 32. OUTLINE OF SPACE DEVELOPMENT IN THE UNITED KINGDOM.

		Name	Contents	Launch yr/mo	Launch vehicle	Weight (kg)	Remarks
National Program	Satellites	Ariel I	Scientific satellites; measurement of electron density, etc.	1962.4	Delta	60	Angle of incidence = = 54° 380 km-1,200 km
		Ariel II	" ; "	1964.3	Scout	68	Ang. of incid. = 52° 290 km-1,400 km
		Ariel III	" ; Measurement of electron density and noise	1967.5	"	90	Ang. of incid. = 80° 480 km-590 km
		Ariel IV	" ; "	1971	"		Ang. of incid.= 80° 550 km circular orbit
		Ariel V	" ; "	1973			
		Skynet I	Military communication satellite; communication	1968.11	Thor Delta	129	Made in the U.S.A.
		Skynet II	"	1973	"		"

TABLE 32 (Continued)

Program	Category	Name	Contents	Launch yr/mo	Launch vehicle	Weight (kg)	Remarks
National program	Satellites	X-3	Technical test satellite; electric source electron device technical test	1971		73	Polar orbit 550 km-1,850 km
National program	Satellites	X-4	" ; Atmospheric phenomena experiments	1973		90	
National program	Launch vehicle	Black Arrow	1st and 2nd stage liquid, 3rd stage solid	1969.6		19t	120 kg in Earth orbit; three launch failures since June 1969 (program suspended)
International Prog.	Launch vehicle	Blue Streak	ELDO 1st stage; launching a geostationary satellite	1964.2		92t	Lox kerosene propulsion 68 × 2

(Source: Japan Rocket Development Council)

b. Attitude on the post-Apollo Program /81

(a). Since there is no one organization corresponding to a space development committee in England, evaluation of the post-Apollo program is carried out individually according to their own situations by the government, industry and related enterprises. They are very interested in the space shuttle, space tug and space station. However, the economic aspect of the systems as well as evaluation of others are not clear until the results of the Phase B study are available.

(b) The British budget for this fiscal year contains £230 thousand pounds (approximately 200 million yen) appropriated for the post-Apollo program study. This is the allotment of the ELDO and ESRO budgets.

TABLE 33. SPACE DEVELOPMENT RELATED BUDGET OF THE UNITED KINGDOM.

(£ 1,000)

		1966/67	1967/68	1968/69	1969/70	1970/71
International cooperation	ELDO	12,540	8,750	9,640	8,170	1,840
	ESRO	3,850	4,500	5,000	5,200	5,450
	INTELSAT	800	600	1,040	1,030	1,130
	POST-APOLLO	—	—	—	—	230
	Subtotal	17,190	13.850	15.680	14,400	8,650
National program	Defence	3.500	4,000	10,700	5,360	6.730
	Commercial Satellite Communication	1.070	1.170	1,310	1.300	1.600
	Scientific Space Res.	2.230	1.960	2,350	2.930	3.930
	Space Technology & Others	2.770	3.170	4,110	3.830	4,640
	Subtotal	9.570	10,300	18,500	13.420	16,900
	Total	26,760	24,150	34,180	27,820	25,550

(Source: Select Committee on Science Technology, British Government)

(c) The British enterprises are participating in the Phase B study of the space shuttle. The government, however, is paying half of the British allotment required for participation (120 thousand pounds). The reason for payment by the government is not only that the enterprises are doing what the government wanted to do but also that the research is useful to aerospace in general rather than limited merely to the space program. /82

The greatest merit of the participation in the Phase B study is obtaining high-value information. It is natural that this information becomes a precious material which will be used in making the decision to participate or not in the post-Apollo program and thereafter. It should be noted that participation in the Phase B study does not mean that it will be extended to Phase C/D.

(d) As far as forecasting the realization of the post-Apollo program is concerned, it is felt that the U.S.A. will carry out this program in one way or another.

TABLE 34. OUTLINE OF SPACE DEVELOPMENTS IN FRANCE.

		Name	Contents	Launch Year	Launch Mo.	Launch vehicle	Weight	Remarks
National Program	Satellites	A-1	Scientific satellite	1965	11	Diamant-A	42 kg	Inclination angle 34° 530 km-1,700 km
		F-R	" VHF propagation research	1965	12	Scout	61	" " 29° 160 km-320 km
		D-IA	Earth Survey Satellite; Doppler technique	1966	2	Diamant-A	39	" " 34° 480 km-2,700 km
		D-IC	" " ; " "	1967	2	"	23	" " 40° 580 km-1,400 km
		D-ID	" " ; Optical, laser technique	1967	2	"	23	" " 40° 580 km-1,900 km
		Peole	Experimental weather satellite; Experimental purpose for EOLE	1970		Diamant-B	64	" " 15° 730 km-860 km
		D-2AB	Scientific Satellite; Long distance ultra violet radiation research	1972 ~ 1973		"	104	" " 46° 470 km-610 km
		EOLE	Weather Satellites Data collection by balloon	1970 ~ 1971		Scout	90	
		Diocurse	Navigation satellite					In the planning stage

TABLE 34 (Continued)

Program	Category	Name	Contents	Launch Yr.	Launch Mo.	Launch vehicle	Weight	Remarks
National Program	Satellite	GEOLE	Earth Survey Satellite					In the planning stage.
		METEOSAT	Stationary weather satellite					" " " "
	Launch vehicle	Diamant A	First stage liquid, second & third stages solid	1965	11		18.5 t	188 lbs at approximately 500 km orbit
		Diamant B	"	1970	3		24.6	254 lbs at approx. 500 km orbit
International Program	Satellites	DIAL (Germany)	Scientific satellites; Earth corona research	1970	3	Diamant-B	115 kg	50 kg is for data gathering part of rocket
		Symphonie (")	Experimental Communication Satellite; Communication satellite	1973		Europa II	360	150 kg is for apogee
	Launch veh.	Coralie	ELDO 2 stages; For launching geostationary satellite				12.0 t	UDMH, N_2O_4 thrust 28 t

(Source: Japan Rocket Development Council)

(e) The merit of participation in the post-Apollo program is that the extended effects on technology are very large.

(f) At present it is not possible to point out exactly what the reactions of the related organizations and general public are to the problem of participating in the post-Apollo program. Also, it seems that they are not particularly concerned with public opinion.

(g) An exchange of information with Japan is most welcome.

The thoughts of the British authorities on the post-Apollo program are more or less as described above. In short, the United Kingdom cannot decide on participation at the present stage since the total picture of the post--Apollo program is not clear and it has not been evaluated sufficiently. However it is diligently collecting information to be ready for the future and watching the other European countries closely, which will help it to decide its attitude.

(2) France

a. Outline

France is the nation which is carrying out the widest range of activities in Europe as far as space development is concerned. It has both the capacity /83 and the past accomplishments of its independent work on satellites, launch vehicles, launch sites and tracking satellites. On the other hand, however, it joined ELDO and ESRO and is putting its efforts into international cooperation such as carrying out common projects with the U.S.A., West Germany, and /84 the U.S.S.R. It is carrying out space development and applications effectively by harmonizing skilfully national programs and international cooperation.

France has been setting up five-year programs for space development and is now in its sixth five-year program which started in 1971 (Table 34 and 35).

The space development program in France is being pursued by CNES (Centre National d'Etudes Spatiales) as a unified organization.

TABLE 35. SPACE DEVELOPMENT-RELATED BUDGET IN FRANCE.
(Unit: 1,000 francs)

	1971		Ratio (percentages)
European Program	195,720		24.31
ELDO		83,083	
ESRO		111,507	
Space Research Headquarters		1,130	
International Program	173,220		21.52
Communications satellite		85,853	
Weather Satellite		54,308	
Rocket		19,400	
National Program	130,870		16.26
Research & Development		31,978	
Observation Rocket		26,599	
Balloon		10,351	
Scientific satellite		33,419	
Technical satellite		11,970	
Rocket		11,420	
Others	305,238		37.91
Research organizations		22,000	
Parts and materials		73,035	
Facility, equipment		178,776	
Others		31,427	
Totals	805,048		100.00

(Source: CNES)

b. Attitude on the Post-Apollo Program /85

Since the officer in charge of the post-Apollo program at CNES was abroad, the policy problems were not discussed but a written reply is expected in future.

By conjecturing from the information obtained from other related persons, France is trying to talk with the U.S.A. via ESC (ESRO/ELDO), keeping in step with other European countries. It seems that a considerable amount of time will be spent before France decides on its course regarding participation.

In addition, the research center of CNES is working on basic research such as heat-resistant materials for the space shuttle, rocket motors, and electronic displays. SNIAS, Thomson CSF and Dassault of France are also participating in the Phase B study of the space shuttle. According to the participation rules, France is paying its own expenses but it is not clear how much is being paid by the Government.

(3) West Germany

a. Outline

The most remarkable characteristic of West Germany in the space development program is that it is based on international cooperation. Its reasons may be the financial problems, the geographical situation which prevents establishing launch sites, as well as political considerations.

The space development program in West Germany has been pursued as an important project since 1962. During this period, it has established organizations such as Aero-space Research Center (DFVLR) and Space Research Company (GfW) with the aid of the Ministry of Education and Science (BfBW). In 1969, a "Space Development Program" (1969 1973) was set up and development is being carried out according to this program (Tables 36, 37).

b. Attitude Toward the Post-Apollo Program /86

(a) The post-Apollo program is rated highly and the West German government is moving in the direction of participation as much as possible. However, the methods as well as conditions are being studied and it is negotiating with the U.S.A. via ESC at the present.

(b) Although Government and academic circles are pushing for participation, there seems to be a problem of balancing it with other items in the budget.

TABLE 36. OUTLINE OF SPACE DEVELOPMENT IN WEST GERMANY.

Program		Name	Contents	Launch Year	Launch Mo.	Launch vehicle	Weight	Remarks
National Program	Satellites	AZUR	Scientific satellite; Cosmic ray research	1969	11	Scout	78 kg	Inclination angle 102° 384 km-3,200 km
National Program	Satellites	A2	" " ; Upper atmospheric research	1972		"	110	250 km-1,000 km
National Program	Satellites	A4	" " ; γ-ray research	1973		"	110	550 km polar orbit
National Program	Satellites	Geophysical satellite	" " ; Measurement of temperature distribution	1974		Scout type		
International Program	Satellites	Symphonie	Experimental communication satellite satellite; communication experiments	1972		Europa II	185 kg	Geostationary satellite. Together with France
International Program	Satellites	HELIOS	Scientific satellites; Interplanet space research	1974 1975		Atlas Centaur	205	0.3 AU Together with the U.S.A.
International Program	Satellites	DIAL	" " Earth corona research	1970	3	Diamant-B	65	5° 330 km-1,600 km Together with France
International Program	Launch V.	Astris	ELDO 3rd stage	1968	11		36 t	A-50, N_2O_4 , Thrust 32.7 t

(Source: Japan Rocket Development Council)

TABLE 37. SPACE DEVELOPMENT RELATED BUDGET IN WEST GERMANY.

Items / Year	Planned amount (1972-73)	1969	1970	1971
I. International cooperation (payment to ELDO, ESRO, etc.)	833,850	142,186	137,096	148,400
II. Research program on exosphere (Grants to the research organizations)	143,000	25,623	17,350	32,100
III. Program on artificial satellites and space exploration	480,500	42,223	64,500	152,500
(1) Research satellite	121,500	22,504	19,500	20,000
(2) Application satellite	215,000	11,796	30,000	60,000
(3) Space probe	144,000	8,923	15,000	72,500
IV. Basic research program	852,420	116,304	113,715	168,930
(1) German space research	53,460	10,045	10,754	14,900
(2) German Aero-space Research Center	302,830	46,500	56,300	72,100
Total	2,310,270	327,336	332,661	501,930

(Source: Japanese Embassy in West Germany)

(c) Supposing that Europe suspends its own rocket (launch vehicle) development and purchases the necessary rockets from the U.S.A. in order to spend the corresponding amount of money, which would be used for its rocket development, for participation in the post-Apollo program, nothing can be said at present as to its merits since it is not known what conditions and what types of rockets will be offered by the U.S.A.

(d) It cannot be exactly ascertained when the decision on the participation will be made.

(e) West German companies are also participating in the Phase B study of the space shuttle. The expenses are paid 100% by the government. /87

(f) The following items may be considered as the merits of participation; (1) contribution to the development of science and technology, (2) profits for industries, (3) extended effects to other industries, (4) political effects and (5) obtaining information.

The thoughts of the West German authorities on the post-Apollo program are more or less as summarized above. It was our impression that West Germany is extremely positive; this was also indicated by the fact that it was thinking of international cooperation as the key to space development.

PART 3. INTERNATIONAL PARTICIPATION AND COOPERATION.

1. Basic Policy

(1) Principal Items

The fundamental ideas of the U.S.A. regarding international participation /88 in the post-Apollo program are clearly shown in its policies which were indicated to ESC etc. by NASA last year. They may be summarized as follows.

a. NASA has an open-door policy for all suggestions.

b. A participating nation should be responsible for the expenses required for the development of the areas in which it is participating.

c. Although an intention to participate may be stated, a nation is not under any obligation until a mutual agreement is reached with the U.S. government in regard to fields of participation, forms and pacts between the governments regarding participation.

d. In case of participation, the required data and information will be open and published.

e. It is necessary to establish a pact between governments to prevent the passing of information to a third nation.

f. Although there is no regulation saying that participation in the application stage is not accepted without participation in the development stage, the project for a nation which has a longer history of participating in the development stage will have higher priority over others if the themes have equal value in the selection of areas of participation.

g. In order to accomplish the program, the management system will be the same as the method used heretofore.

h. It is necessary to have an equivalent technology in order to exchange technical information required in the course of cooperation.

i. It is desired to have a wider range of international cooperation for this program. Therefore, it will be ideal if many nations cooperate. However, there will be no objection even if the cooperation is temporarily between only two nations.

(2) Other Related Items /89

a. The U.S.A. hopes strongly for international participation in this program. However, it is clear that it intends to accomplish it by itself if international participation does not work out.

The U.S.A. is not expecting any cooperation with the Soviet bloc since there is no technical interchange, and so on. Also, it does not have any intention of forming an international supervisory organization such as INTELSAT at the present time.

b. It is not an easy problem to answer in general terms how much consideration will be given to the particular situation of each nation in participation. Therefore, it is necessary to negotiate by presenting a concrete proposal.

Also, it seems that no clear answer will be obtained regarding the form of participation, e.g., participation only in software, tracking, data collection or offering the ground facilities, unless a concrete proposal is discussed.

c. The coordination of proposals by each nation will be carried out by forming a joint committee. As far as systems engineering is concerned, each nation may carry it out according to its own technique if it is independent of other systems. For example, the management of the space tug and RAM, which are independent of the station and shuttle, may be carried out independently. In this case, however, it is necessary to form a joint committee to coordinate the assembly of the tug and shuttle.

In cases such as manufacturing the elements of the shuttle, it is necessary to have a unified management system. Thus, the foreign companies will become the subcontractors of the U.S. enterprises. Even in these cases; the expenses of a nation will be covered by its own government according to the principles of participation. Moreover, within the limit of managerial necessity, the U.S. enterprise which is the prime contractor will have a voice in the disbursement of the funds provided by the foreign government.

d. In regard to whether the NASA budget will be cut by the corresponding amount in case of participation by foreign countries, the opinion of NASA was that there would be no budget cut since expenses will be necessary for management if the foreign countries participate. /90

2. Problems of Our Nation in Participation

Since there has been no really close correspondence between NASA and the government of Japan and Japanese industries in the past, NASA expressed great interest in promoting mutual exchange of information in the future. As the first step, they indicated that it might be proper to exchange information concerning related fields in Japan and the technical level in Japan.

They also indicated a strong possibility of agreement if Japan asks to send their representatives to committees in NASA in regard to this program, as the European countries do. It seems that they would also welcome the establishment of a communications system between Japan and Europe.

NAMES OF THE MEMBERS OF THE LONG-RANGE SPACE PROGRAMS STUDY TEAM /91

(Arbitrary Order)

Tetsuya Chiga (Head)	Executive Director, Federation of Economic Organizations
Terno Ichinose	Councillor for Space Development, Science and Technology Agency (participated in part of trip)
Shinichi (or Nobukazu) Uematsu	Executive Director, Nippon Electric Co., Ltd.
Tetsuro Hikida	Director, Mitsubishi Heavy Industries, Ltd., Chief of Space Apparatus Section, Headquarters of Aircraft Division
Yasuaki Toda	Director, Nissan Motor Co., Ltd., Chief of Space and Aeronautics Section
Sei Matsudaira	Director, Ishikawajima-Harima Heavy Industries, Ltd., Chief of the Technical Development Section
Toshiya Kashimoto	Director, Mitsubishi Electric Co., Ltd., Deputy Chief of the Electronics Division
Horoyuki Ueda	Tokyo Shibaura Electric Co., Ltd., Deputy Head of Space Development Headquarters
Fumihiko Mizutani	Staff, Budget Bureau, Ministry of Finance (in charge of Science and Technology)
Toshihiko Saijo	Nippon Electric Co., Ltd., Deputy Chief of Space Development Headquarters
Takuya Hirano	Secretary of General Affairs, Space Development Association
Kazuo Koike	Member, Federation of Economic Organizations

ITINERARY AND DESTINATIONS OF THE STUDY TEAM

June 26 (Saturday)	Leave Haneda Airport, Japan
27 (Sunday)	Arrive London (H)
28 (Monday)	Visit British Department of Trade and Industry

Research and development of rockets and satellites

Mr. A. Goodson, Undersecretary
Space Division
Department of Trade and Industry /92

Leave London (H)

Arrive Bonn

29 (Tuesday) Visit Ministry of Education and Science of West Germany

Formation of space development program, space research and international cooperation

Visit Space Research Company, Ltd.

Development and production of rockets and satellite instruments, Training of technicians

Dr. Armin Spaeth
Reg. Director
Bundesministerium fuer Bildung und Wissenschaft

Dr. Johann Mader
Program Coordinator
Gesellschaft fuer Weltraumforschung mbH

30 (Wednesday) Leave Bonn

Arrive Munich

Visit MBB

A company formed by combining Messerschmitt, Boelkow and Blohm

This company handles 50% of German space development.

System design of satellites, integration, general testing and development of rocket engines.

Dipl. Ing. Julius Henrici
General Manager
Space Division
Messerschmitt-Boelkow-Blohm GmbH

Leave Munich

Arrive Paris (O)

July 1 (Thursday) Visit CNES /93

Space research headquarters of France.
Space development, formulation of research programs (Decision will be made by a committee representing each ministry), execution, international cooperation.

Mr. G. Marceaux
Chief
International Affairs
Centre Spatial de Bretigny
Centre National d'Etudes Spatiales

July 2 (Friday) — Visit ESC (European Space Conference)

Highest organization, whose aim is to coordinate space development in Europe.
Organized by Cabinet members from each nation.

H. E. Ambassador R. di Carrobio
Secretary General
European Space Conference

ESRO (European Space Research Organization)

Ten European nations participate. Space research, various experiments by using rockets and research and development of satellites.

Dr. A. Hocker
Director General
European Space Research Organization

ELDO (European Launcher Development Organization)

Participation of seven European nations. Development of rockets (launchers) by European technology.

Mr. Jean-Pierre Causse
Deputy Secretary General
European Launcher Development Organization

July 4 (Sunday) — Leave Paris (O)

Arrive San Francisco

6 (Tuesday) — Visit Ames Research Center of NASA

(Moffett Field)

Basic application research of physics and life sciences /94
in aerospace technology. Also, re-entry heat problem of Apollo and development of guide systems.

Dr. Hans M. Mark
Director
Ames Research Center, NASA

Visit Lockheed Missiles and Space Co.

Manufacturing missiles, artificial satellites and propulsion systems. Research on "manned" and "unmanned" programs as well as space shuttle and space tug.

Mr. J. P. Nash
Vice President and Assistant General Manager
Lockheed Missiles and Space Company

Mr. D. P. Germeraad
Manager
Systems Test and Operations
Manned Space Programs
Lockheed Missiles and Space Company

July 7 (Wednesday) Leave San Francisco

Arrive Los Angeles

Visit Jet Propulsion Laboratory (JPL) of NASA (Pasadena)

Advanced research and development on the future technology required in the Space program. Unmanned Moon explorer and planet explorer development.

Dr. William H. Pickering
Director
Jet Propulsion Laboratory, NASA

8 (Thursday) Visit TRW, Inc. (Redondo Beach)

In charge of systems engineering on the THOR, ATLAS, TITAN and MINUTEMAN. /95

Engaged in 90% of satellite-related works
Development of various software for post-Apollo program.

Dr. E. B. Doll
Vice President and Assistant General Manager
Systems Group of TRW, Inc.

Mr. D. N. Lowrey
Director
Far East Activities
Systems Group of TRW, Inc.

Visit North American Rockwell Corp. (Downey)

Manufacturing various rockets and Apollo Command service modules.

Research on space shuttle, space station and others related to exploration.

Mr. J. W. Sandford
Project Director
Program Development and Plans
Space Shuttle Program
Space Division
North American Rockwell Corp.

Mr. Alan Lehman
Vice President
Far East Area
North American Rockwell International.

Drive to San Diego

July 9 (Friday) — Visit General Dynamics (Convair Aerospace Division)

Development and manufacturing space-related rockets such as Atlas Centaur.

Researches on space shuttle and especially that using Centaur; life science and other manned and unmanned related projects. /96

Mr. R. J. Lutz
Director
Convair Aerospace Division
General Dynamics

Leave San Diego

Arrive Las Vegas

11 (Sunday) — Leave Las Vegas

Arrive St. Louis

12 (Monday) — Visit McDonnell Douglas

Manufacturing rockets such as Thor-Delta, Saturn V.

Research on space-related problems beginning with space shuttle

Dr. B. G. Bromberg
Vice President and General Manager
McDonnell Douglas Astronautics Company-East

Leave St. Louis

Arrive Houston

13 (Tuesday) — Visit Manned Spacecraft Center (Houston)

Development of satellites for manned flight and operations. Training crews.

Dr. Robert R. Gilruth
Director
Manned Spacecraft Center, NASA

14 (Wednesday) — Leave Houston

Arrive Huntsville

15 (Thursday) — Visit Marshall Spaceflight Center of NASA

Development of rockets and space transportation systems.

Dr. Eberhard Rees
Director
George C. Marshall Spaceflight Center, NASA /97

Dr. E. W. Neubert
Deputy Director
George C. Marshall Spaceflight Center, NASA

Leave Huntsville

Arrive Washington, D. C. (N)

16 (Friday) Leave Washington, D. C. (N)

Arrive Hampton (NPN)

Visit Langley Research Center of NASA

Research on rocket shapes, materials, structure and flying mechanisms.
Development of life support and continuous communication techniques during re-entry.

Dr. O. W. Nicks
Deputy Director
Langley Research Center, NASA

18 (Sunday) Leave Hampton (NPN)

Arrive Washington, D. C. (N)

19 (Monday) Visit NASA headquarters

Dr. James G. Fletcher
Administrator
National Aeronautics and Space Administration

Dr. George M. Low
Deputy Administrator
National Aeronautics and Space Administration

Mr. Arnold W. Frutkin
Assistant Administrator
Office of International Affairs
National Aeronautics and Space Administration

20 (Tuesday) Visit Goddard Spaceflight Center of NASA (Greenbelt) /98

Development of scientific satellites, weather satellites and communication satellites.

Determination of satellite orbits.

Dr. M. J. Vaccaro
Deputy Director
Goddard Spaceflight Center, NASA

Mr. Gilbert W. Ousley
Chief
International Projects Office
Goddard Spaceflight Center, NASA

Group disbanded here.

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TABLE OF ABBREVIATIONS

ABEs = Air Breathing Engines

ACPS = Attitude Control Propulsion System

AM = Airlock Module

APS = Auxiliary Propulsion System

ATM = Apollo Telescope Mount

ATS = Applications Technology Satellite

CAS = Canadian Applications Satellite

CDR = Critical Design Review

CM = Crew Module

COOPS = Cooperative Application of Satellite

CQM = Crew Quarter Module

CSM = Command and Service Module

DUAL AIR DENSITY = State University of Iowa Program to measure air density

ECS = Environmental Control System

EOS = Earth Observations Satellite

EOS = Earth to Orbit Shuttle

EPS = Earth Physics Satellite

ERTS = Earth Resources Technology Satellite

FAS = Fixed Airlock Shroud

FMOF = First Manned Orbit Flight

HEAO = High Energy Astronomical Observatory

IMP = Interplanetary Monitoring Platform

Interfer. Teles. = Interferometer Telescope

ISIS = International Satellite for Ionospheric Studies

LGE RADIO OBSERV. = Large Radio Observatory

LH_2 = Liquid Hydrogen

LL = Landing Legs

LOX = Liquid Oxygen = LO

LSO = Large Stellar Observatory

LST = Large Space Telescope

MDA = Multiple Docking Adapter

OAO = Orbital Astronomy Observatory

OOS = Orbit to Orbit Shuttle

OSO = Orbiting Solar Observatory

OWS = Orbital Workshop

PM = Propulsion Module

PPE = Primary Propulsion Element

RAM = Research and Applications Module

RTGS = Radioisotope Thermoelectric Generators

SAS = Small Astronomy Satellite

SATS = Small ATS

SEOS = Synchronous Earth Observations Satellite

SMS = Synchronous Meteorological Satellite

SPE = Secondary Propulsion Element

SSS = Small Scientific Satellite

TOPS = Thermoelectric Outer-Planet Spacecraft Project

UDMH = Unsymmetrical Dimethyl Hydrazine

TABLE OF ABBREVIATED CODES OF COMPANIES AND RESEARCH CENTERS. /100

BAC = British Aircraft Corporation

BFBW
BMBW = Bundesministerium für Bildung und Wissenschaft

CASA = Construcciones Aeronauticas, S. A., Spain

CIR = Compagnie Industrielle Radioélectrique

CNES = Centre National d' Études Spatiales

DFVLR = Deutsche Forschungs-und Versuchsanstalt für Luft-und Raumfahrt e. V.

DOD = Department of Defense

ELDO = European Launcher Development Organisation

ERNO = Erno-Raumfahrttechnik GmbH

ESC = European Space Conference

ESRO = European Space Research Organisation

ETCA = Études Techniques et Constructions Aerospatiales

GfW = Gesellschaft für Weltraumforschung mbH, Bad Godesberg

HSD = Hawker Siddeley Dynamics

JPL = Jet Propulsion Laboratory

KSC = Kennedy Space Center

LeRC = Lewis Research Center

LRC = Langley Research Center

MBB = Messerschmitt-Bölkow-Blohm

MDAC
MDC = McDonnell Douglas Corporation

MSC = Manned Space Center, Houston

MSFC = Marshall Space Flight Center

NAR
NARC = North American Rockwell Corporation
NR

NASA = National Aeronautics and Space Administration

SAAB = SAAB Aktiebolag, Sweden

SABCA = Société Anonyme Bélge de Constructions Aeronautiques

SEP = Société Européenne de Propulsion par Reaction

SNIAS = Société Nationale Industrielle Aerospatiale

TCSF = Thomson-CSF

VFW = Vereinigte Flugtechnische Werke GmbH

Translated for the National Aeronautics and Space Administration under contract No. NASw-2037 by Techtran Corporation, P. O. Box 729, Glen Burnie, Maryland 21061, translator: Chan Mo Park, Ph.D.